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AUG 76 W MERRITT, R WESTHAVER, K MILLO F33615-74-C-1105
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MICROCOPY RESOLUTION TEST CHART
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AFAL-TR-76-150

MICRO-ELECTROSTATIC GYRO (MESG)

MESG SECOND SOURCE DEVELOPMENT PROGRAM

Precision Products Department
Northrop Corporation
Norwood, MA 02062

August 1976

Technical Report AFAL-TR-76-150
Final Report June 1974 – April 1976

Approved for public release; distribution unlimited.

AIR FORCE AVIONICS LABORATORY
AIR FORCE WRIGHT AERONAUTICAL LABORATORIES
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The objective of the MESG Program was to develop a competent second source for the fabrication of MESG rotor and cavity sets. This was required in order to protect the Government's investment by insuring that the drawings, procedures, and techniques developed by the prime contractor (Autonetics Group, Rockwell International-AGRI) were correct, and to prevent AGRI from obtaining a sole source advantage.

PPD's major function in the program was to demonstrate to the Air Force that PPD could produce MESG rotor and cavity sets with equal proficiency as AGRI.

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As preliminary to this major function, PPD; 1) reviewed (and updated and corrected, as required) a Reprocurement Data Package supplied by the Air Force to ensure its completeness and suitability; 2) established alternate sources for required raw materials and beryllium billet extrusions; and 3) procured or designed and fabricated baseline tooling and fixtures necessary to produce MESG rotors and cavities.

In its fabrication activity, PPD first built six rotor and cavity sets using materials supplied by the Air Force. After AF approval of this first lot, PPD then built four rotor and cavity sets using materials supplied from the alternate vendors. (A further requirement for 10 additional sets using alternate source material was deleted from the contract.)

Ancillary program activity included: 1) a Product Improvement Task in which PPD investigated and recommended alternate rotor/cavity processing and production techniques to reduce costs; 2) development of reliability and maintainability factors involved in fabrication; and 3) performance of a preliminary system safety analysis.

PPD believes that it has met or exceeded all the goals called out in the contract (and revisions thereto currently in process by AFAL) and is ready to perform as a competent second source for any future MESG rotor/cavity fabrication requirements.

FOREWORD

This final report was prepared under Air Force Contract F33615-74-C-1105, Item 0002, Task A006. The report covers work performed by the Precision Products Department of the Northrop Corp., 100 Morse St., Norwood, Mass. 02062 for the Air Force Avionics Laboratory, Wright-Patterson Air Force Base, Ohio.

The purpose of this development effort was to establish a second source for MICRO-Electrostatic gyro (MESG) rotors and cavities, to protect the Government's investment by insuring the drawings, procedures, and techniques obtained from Autonetics were correct, and to prevent Autonetics from obtaining a sole source advantage.

This program was conducted from June 1974 through April 1976 under the direction of the following personnel:

W. Merritt	MESG Program Manager
R. Westhaver	MESG Project Engineer

The principal contributors to this report were:

K. Millo
R. Pagels
F. Hallock

The cognizant Air Force Project Manager on this MESG program was Captain Walter Peterson, Jr., AFAL/RWM-666A.

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Section I

SUMMARY

The objective of this advanced development effort was to establish a second fabrication source for the rotors and cavities of the MICRO-Electrostatic Gyro (MESG). Work was performed by Northrop Corporation's Precision Products Department (PPD) under Contract Number F33615-74-C-1105, covering a time period from 3 June 1974 through 30 April 1976.

The Statement of Work called out six major tasks to be accomplished in meeting the program goals:

Task 1. Documentation Package Review – This task required that PPD review a Reprocurement Data Package supplied by the Air Force to determine its completeness and suitability for use in fabricating MESG rotors and cavities and associated tooling and fixtures. Altogether, 16 gyro drawings and revisions, 43 specifications and revisions, and 104 tool drawings and revisions were reviewed. The review revealed numerous mistakes, omissions, and/or need for clarifications in each category. These deficiencies have been corrected, and PPD now has in its possession all available and necessary documentation needed to comply with the MESG program.

Task 2. Establish Alternate Sources for Raw Materials – This task required that PPD establish MESG raw material and processing sources other than those being used by the Autonetics Group of Rockwell International (AGRI) in its prime contract activity. Four vendor surveys were conducted by PPD in completing this task. Two vendors were selected as possible new sources: Kawecki Berylco Ind., Inc. Reading, Pa. for beryllium stock, tantalum wire, and extrusions; and Brush Wellman Co., Elmore, Ohio for beryllium oxide discs. PPD also developed two material specifications (as part of this task) to completely define the material and inspection requirements.

Task 3. Tooling for Baseline Configuration – This task required that PPD either procure or design and fabricate the tooling and fixturing necessary to produce MESG rotors and cavities. Existing fixtures and tools were used "as-is" to the greatest extent possible; two fixtures were modified for use; and 16 items were especially developed for MESG.

Task 4. Fabrication – This task required that PPD fabricate six rotor and cavity sets using materials supplied by the Air Force. After AF approval, it required fabrication of four rotor and cavity sets using materials procured from the alternate sources developed in Task 2. A further requirement for fabrication of ten additional sets using alternate source material was deleted from the contract. The original six rotor and cavity sets were completed by May 1975. The four sets using alternate vendor material were completed in January 1976.

Task 5. Product Improvement – This task required that PPD investigate and recommend alternate rotor/cavity processing/production techniques to reduce costs. After preliminary consideration of several areas of investigation, emphasis was placed on new techniques for stock removal from eloxed rotors using barrel and vibratory tumbling. These techniques showed great potential for cost effective results in production.

Task 6. Design Reviews – Two design reviews were originally scheduled; however, this task was later deleted.

In addition to these specific numbered tasks, the SOW also required that:

1. Careful consideration be given throughout the program to the factors of reliability and maintainability, and that a prediction of the degree of these factors be developed. This was completed with the development of a summary of reliability/maintainability factors.

2. A preliminary system safety analysis be performed. Special precautions were incorporated:

   a) to ensure personnel safety in all operations involving the processing of beryllium and beryllium oxide, and

   b) to minimize loss of in-process parts from accidental causes.

PPD has completed and complied with all requirements in the SOW (and revisions to the contract currently in process by AFAL). This Final Technical Report documents all program activity, results, and recommendations.

Section II
TASK 1, DOCUMENTATION PACKAGE REVIEW

INTRODUCTION

This task, as established by the SOW, required PPD to review a Reprocurement Data Package supplied by the Air Force and report on its completeness and suitability for fabricating MICRON rotors and cavities and associated tooling. The Data Package as received consisted of four piece-part drawings, 75 tooling drawings, and three process specifications. After these documents were reviewed, it became apparent that additional data referenced in the Data Package would be required and this data was requested. The review also revealed that some documentation, which PPD felt was required to completely define rotor fabrication, was not included. Such data included information on the billet extrusion process, and assembly drawing of the billet and tantalum wires, details of the billet showing size and location of the wire slots, oxidization process for the billet, and the billet assembly procedure. A total of 16 gyro drawings and revisions, 43 specifications and revisions, and 104 tool drawings and revisions have been reviewed.

A complete list of Documentation Data required to produce MESG rotors and cavities is given in Appendix A of this report. Shown is a list of AGRI tools, piece-part drawings, and specifications. Appendix B contains two Material Specifications developed by PPD during the Program.

The following comments on the Reprocurement Data Package were forwarded to the Air Force and resulted in changes to some of the drawings.

TOOLING

<u>10000-207, Rotor Lapping Machine, ESG</u>

All detail drawings indicated by the main assembly drawing have been received and have been found to be inadequate to produce a machine capable of hot lapping rotors.

Item 6 of this drawing shows two ¼-20 socket head screws, but does not specify the material; PPD thinks that the material should be teflon or nylon in order to minimize heat loss from the block. PPD also believes that item 65, Shield, is not properly placed and should be placed between item 4, Cartridge Holder, and item 5, Insulator, rather than item 4 and item 1, Base. This is recommended so that the heat radiated from the block to the shield has direct contact with the base plate, so that between the ¼-20 screws and the shield, the base plate becomes a large heat sink. In addition, nowhere in the parts list or on the drawing is reference made to placement, size, or capacity of the heater, sensor, and controller, required to maintain the rotor at lapping

temperature. PPD has learned from experience that assembly of the lapping machine is not altogether straightforward and believes a procedure should be written covering the assembly and checkout of the unit.

10032-207, Comparator, Cavity Spherometer, ESG

All detail drawings related to this assembly have been received. PPD has built this fixture and has found numerous mistakes and omission in the drawings which required revision before a workable instrument could be made. These deficiencies must be corrected before usable instrumentation can be fabricated. PPD has kept a set of red-lined drawings recording the required changes.

10039-207, Comparator, Cavity Equator, ESG

All detail drawings related to this assembly have been received. Based on experience PPD has gained in building this fixture, revisions in the drawings are required before usable instrumentation can be fabricated from these drawings. PPD has marked-up drawings.

10077-207, Cavity Holder (hand lapping)

An addition to this drawing is required to show the ball rotating fixture.

10078-207, Mask, Sputter

This mask does not adequately shield the back side of the cavity from extraneous sputtered material.

10080-207, Cavity Grind Fixture

This drawing reflects the fixture for cavity outside diameter grind and alignment. PPD noticed that according to this drawing, item 3, Alignment Ball, has been changed to 0.406235 dia. from 0.406241 dia. PPD feels that one rotor will not suffice for the concentric grinding and alignment operation because of the large variation in cavity diameters. We believe it will take 3 rotors of varying size in order to hold the alignment tolerance specified.

10083-207, Probe, Temperature – Rotor Lapping Machine

PPD questions how the probe is used in order to insure no rotor damage due to scratches, because there is no sphericity lapped into probe end. Also, the measurement of temperature may not be accurate due to this point contact.

10089-207, Rotor Measuring Fixture – Talyrond

The spherical diameter is shown as 0.405650 ± 10μin. This is the diameter of the Marine rotor. The Micron rotor has two different diameters at 68°F. PPD questions whether the vacuum would be sufficient for all diameters. Because the rotor is oblate, it seems probable the rotor could move and also it may not seal the fixture; hence, the vacuum would be insufficient to hold the rotor.

PPD also questions the fact that the rotor seat is made from stainless steel. Even though it has a 2μin. finish, the rotor has to be rotated for different scans. PPD believes the rotor could be damaged doing this.

10090-207, Bake Fixture, Rotor

This fixture specified a spherical diameter of 0.405650 which does not appear to be compatible with the 0.406050 and 0.405950 spherical diameters which the Micron rotors have when this fixture is used. Also, this fixture has no protection against the rotor falling out of the fixture; it should have some sort of counterbore or lip to catch the rotor if it rolls out of the fixture.

SPECIFICATIONS

AA0109-051, Electroless Deposition of Nickel – Phosphorous Plate on Gold

A procedure is required for reworking plated cavities, including the number of reworks permitted.

AB0170-067, Beryllium Extruded

Pg. 2, par. 1.0; The extrusion ratio for Micron of 25 to 1 should be specified.

Pg. 6, par. 4.2.3.2; The number of samples and their location for the thermal expansion anisotropy test should be specified. Also, the absolute coefficient of expansion is required in order to be able to correct finished rotor size for the temperature at which it is measured. The temperature over which these tests are run should also include points below room temperature. A value and tolerance of coefficients determined should be specified.

Pg. 6, par. 4.2.3.7; The diametral positions for the three wire extrusion are required.

AL70030, Rotor; Hot Lapping Procedure For

This document outlines the procedure for fabricating the MICRON rotor. The equipment listed is adequate as given except as noted below.

For sizing the rotors during the fabrication cycle, PPD uses air-buffered electronic indicators in place of the mechanical Mikrokator listed. PPD has found the electronic indicators offer superior repeatability over the Mikrokators. The equipment specified for measuring the rotor temperature (the Leeds and Northrop Potentiometer) is not complete because no description or drawing of the thermocouple probe used to contact the rotor is given.

In par. 3.1.6.1, the hot lap mixture as stated is incomplete.

In par. 3.2.1.1, minimum rotor size out of EDM is specified as 0.418 in. In conversations with AGRI, it was learned that rotors as small as 0.412 in. are processed. The actual determining factor of how small the rotor can be is the depth of pitting made by the Eloxing process; consequently rotors smaller than 0.418 can be used provided they are not pitted too badly.

In par. 3.2.3.1, the direction of rotation for the cycle drive and rotating disc is not specified.

In par. 3.2.3.2, if the pits and scratches appear to be too deep to clean up in subsequent lapping operations, the rotor must be rejected.

In par. 3.2.3.6, PPD prefers to use a soft felt-tipped pen rather than the Rapidograph pen specified because of the danger of scratching the ball with the Rapidograph.

In par. 3.2.3.7, a more definitive statement regarding exactly what is acceptable and rejectable in terms of wire condition is needed. X-ray pictures showing examples of acceptable and rejectable rotors should be provided.

In par. 3.2.4, PPD has added an additional lapping operation in which the rotor is lapped with 38-900 compound. PPD has found this additional step reduces the time required to remove scratches made by the 38-500 compound.

In par. 3.2.4.5, the reference temperature at which the ball size is to be determined should be stated. Room temperature is not accurate enough.

In par. 3.2.4,7, a tolerance should be placed on the 30 microinch oblateness. With the stated size tolerance, this could be interpreted to be ± 15 microinches.

In par. 3.2.5.6, after obtaining the roundness sweeps, no criteria or information are given regarding how (or if) this information is to be used for accepting or rejecting a rotor. As this paragraph stands, the data obtained is for information purposes only.

In par. 3.2.7.9, the tolerances on the rotor diameters are given as ± 5 microinches whereas in figure 2 and on drawing 12504-302, the tolerance is given as ± 10 microinches. It is not known if this is intentional or an oversight.

Pg. 4 item 23, part number not identified.

Pg. 4 items 36, 37, and 38, not adequately identified or vendors specified.

Pg. 5 Environmental requirement, par. 3.1.2, the temperature specified of 72 ± 5°F disagrees with rotor drawing 12504-302 which specifies 75 ± 5°F.

Pg. 6 par. 3.2.1.3, specifies that a porcelain disc is used. This could bring about contamination from glass.

AL70032, Cavity, Rotor; Lapping Procedure For

This document outlines the procedures for fabricating the cavity halves after plating (P/N 12699-302) and the cavity matched set (P/N 12700-302).

Par. 3.2.1.1 calls for stripping and replating the cavity half if loose, blistered, or excessive plating is present. PPD needs to know if there is a limit to the number of times the plating can be stripped.

For par. 3.2.6, PPD will need a series of matched set control numbers for identifying the cavity sets.

In par. 2.1, Documents Required by this Specification include AA0110-003, Cleaning of Beryllium. The callout number is in error and should be AA0110-008.

The equipment listed in par. 2.3 is adequate to perform the task outlined with the following comments. Item 1, Lapping Machine, Cavity, Dwg. No. 10056-207 has not been built by PPD, nor is it actually needed. PPD has had good success lapping cavities with item 2 and 23 and intends to continue to use this equipment rather than item 1. Item 20, Master Cavity, is required for use in the Spherometer for sizing the cavities. PPD possesses a Master Cavity but requires a periodic recall system for certification through Autonetics Metrology.

In the equipment list, item 5 should be changed to reflect the drawing requirement for 1000 megohms resistance at 250 VDC. Par. 3.2.2.7 should also be changed to indicate the need for a megohmeter check.

The following comments apply to the procedure.

In par. 3.1.2, the temperature at which operations are to be performed is listed as 72 ± 5°F. This tolerance is too loose when sizing the cavities. A reference temperature at which the size is to apply should be stated with the actual temperature at which measurements are made being recorded. Piece-part dimensions would then be referenced to the standard temperature by computation.

Pg. 3 item 3, Rough Cavity Lapper: drawing number not specified.

Pg. 4, par. 3.1.3.1, Cleaning of Parts: the pressure of the spray that is used to clean parts is not specified.

Pg. 5, par. 3.1.5.2, Charging of cavity lap: the drawing number of the lap charge holder is not specified.

Pg. 8, par. 3.2.3.6, the lap "used for polishing cavities" requires further definition as to the lap used and the lapping compound. The temperature at which the cavity diameter dimension applies needs to be specified.

Pg. 8, par. 3.2.3.10, the equator location requires better definition.

Pg. 9, par. 3.2.4, Final Measurement: the roundness of each sweep should be specified.

Pg. 11, an explanation as to why the meter is set to read – 7 is required. Additional instructions and information such as coefficients of thermal expansion are required for size correction due to temperature.

Pg. 12, an explanation as to why the meter is set to read – 3.5 is required.

DRAWINGS

12698-302, Cavity, Rotor

1. No surface finish designation for the equator plane is indicated on the revised drawing, whereas it was indicated on the previous version.

2. No roundness is specified for spherical dia.

3. No surface finish is specified for spherical dia.

4. There should be a definite surface specification for the equator, because it is difficult to check equator depth or hemisphere size unless this surface is lapped flat prior to measurement. The flatness should be 2 microinches.

5. The temperature at which the critical dimensions apply should be specified.

12699-302, Cavity, Rotor Plated

1. Location of equator with respect to center of the 0.406250 spherical diameter requires clarification.

2. The temperature at which the critical dimensions apply should be specified.

3. Note 9; index mark should be on drawing 12700 and not on this drawing.

4. This drawing does not reflect roundness nor surface finish.

5. "Plate thru holes" will allow the plating to contact the Support Ring. Holes should be relieved to prevent this.

12700-302, Cavity Assembly, Rotor

A note on index mark location and dimensions should be added.

The machining of the 0.680 diameter and rear face of one cavity does not call out perpendicularity between the cavity OD and the step. This call-out is needed because it affects the operation of the external cavity alignment fixture.

12504-302, Rotor

Several comments are required on this drawing.

1. There is no specification of roundness on the major diameter; consequently, roundness could be within the size tolerance of ± 5 microinches. PPD feels this should be specified.

2. Note 2 specifies a machining spec to be followed in fabricating the rotor. This spec, ST0115AA0010, is a general machining spec regarding tolerances, surface, finish, etc. and gives no information regarding the fabrication process. It would seem appropriate to add a note referencing AL700030 which is the hot-lapping procedure.

3. The intent of note 5 regarding the temperature at which final dimensions are to be measured is not clear. The 10°F tolerance allowed on the temperature represents a diameter change of approximately 26 microinches, or 2.6 times the allowable tolerance of the major diameter. Therefore, a part which is close to the nominal requirement could be brought into tolerance by merely changing the temperature at which the measurement is made. PPD needs to know if the nominal diameter dimensions specified are to apply at the 75°F with correction factors being applied to measurements made at other temperatures, or if the measurements can be made anywhere within the temperature range.

4. No surface finish is specified. PPD realizes the difficulty of specifying surface finishes of this type; however, this is a possible area of confusion between PPD and Autonetics when these parts are inspected. An agreement between AF, PPD, and AGRI should be reached regarding this requirement.

5. The material called out on this drawing is beryllium rod. Rotors made from this material would contain no tatalum wire, obviously not the intent. This callout should be changed.

Section III

TASK 2, ESTABLISH ALTERNATE SOURCES FOR RAW MATERIALS

INTRODUCTION

This task required that PPD establish sources different than those being used by Autonetics for the critical materials and processes used to fabricate the MESG rotors and cavities. The materials and processes which require alternate sources and the sources used by Autonetics are listed below.

Material/Process	Source
Beryllium	Brush Wellman, Inc. 14450 Nindry Ave. Lawndale, CA 90260
	Kawecki Berylco Ind., Inc. 3711 Long Beach Blvd. Long Beach, CA 90807
Tantalum Wire	Norton Metals Division 45 Industrial Place Newton, MA 02164
Beryllium Oxide	3-M Company Technical Ceramics Products 6023 S. Garfield Avenue Los Angeles, CA 90040
	Ceradyne, Inc. 8948 Fullbright Avenue Chatsworth, CA 91311
Extrusion	Nuclear Metals Division 2229 Main Street Concord, MA 01742

VENDOR SELECTION

PPD conducted vendor surveys to qualify possible new vendors. The vendors included:

- American Beryllium Company for both beryllium bar stock and beryllia blanks.

- Coors Company for beryllia blanks.

- Brush Wellman Company for beryllia blanks and the extrusion.

- Kawecki Berylco Company for beryllium stock, tantalum wire, and extrusions.

Several other sources were contacted for the extrusion; however, only Brush Wellman and Kawecki Berylco provided quotes. Both companies agreed to extrude the beryllium billet only from their own beryllium stock. After discussion with the Air Force, KBI was selected. While KBI was a secondary source of beryllium stock for Autonetics, it was equally improtant to develop another source for the extrusion.

PPD engineers visited KBI's facility on 14 February 1975 and discussed the requirements for alternate source. The major topic of the discussion concerned specific documents (AGRI's Drawings 12795, Billet, Extrusion; 12796, Extrusion Rotor and AGRI's Specification AB 0170-067).

KBI felt that they could meet the acceptance requirements of AB 0170-067 with two exceptions:

1. Paragraph 3.2.2.

   Straightness could be met provided roll or die straightening was permitted.

2. Paragraph 3.2.3.

   Diameter – KBI felt the specification requirement could be met provided 0.002 to 0.004 in. of material could be etched off after the material was extruded. KBI agreed to quote on the extrusion based on the specifications and above exceptions. PPD stated that they would require documentation such as X-ray and other inspection criteria to assure compliance with drawings. KBI was also asked to submit a quote on preparing documentation required to control the extrusion process.

This meeting convinced PPD that KBI could supply the beryllium sleeve, beryllium rod, and tantalum wire and could extrude the beryllium billet after PPD did the machining and assembly.

DETAILS OF KBI EXTRUSION

The extrusion received from KBI consisted of the three sections shown in figure 1. The overall length of the extrusion was 113-7/8 inches. The nose and tail sections are not usable, so that the usable section of the extrusion is the 88-1/2 inch length of body. Examination of this section by X-ray showed that only one half of the body (nearest the tail end) had wires that were continuous. Figure 2 shows an analysis of the extrusion. The lower curve shows the diameter (left vertical scale) measured in two perpendicular directions every 2 inches along the length of the extrusion. The right vertical scale is the extrusion ratio calculated from the beryllium billet

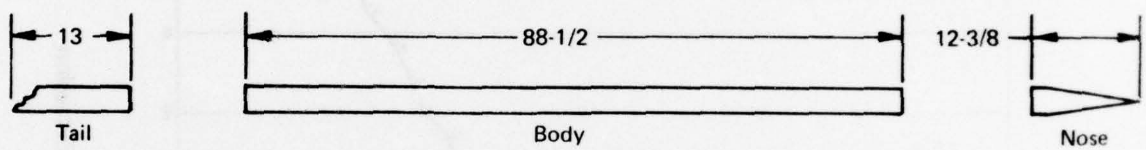


Figure 1. Beryllium Extrusion

dimensions and the diameter measurements of the extrusion. It can be seen from this curve that the most uniform section of the extrusion is from 10 inches to 60 inches. However, the extrusion ratio for this length is 24.2, less than the desired ratio of 25.

The top curve shows the bolt circle radius established by the three tantalum wires. The left vertical scale is the wire bolt circle radius. The right vertical scale is the extrusion ratio calculated from the wire locations in the billet and the measured location of the wires in the extrusion. The wire bolt circle radius was measured on each end of five 7-1/2 in. long segments.

The specified wire length when the rotor diameter is 0.406050 in. is 0.203 ± 0.010 in. This length requires a wire bolt circle radius of 0.1728 to 0.1786. This was achieved in only one 7-1/2 in. length of the extrusion because the actual extrusion ratio was less than the required ratio of 25 to 1. KBI feels, and Northrop agrees, that this can be corrected in subsequent extrusions.

The extrusion process is defined by KBI drawing ZHC-4117, Rev. B, and by Standard Operating Procedures numbered:

614-310-05.001	730-975-05.001
614-310-05.002	730-988-05.001
614-310-05.003	1200-000-08.008
640-999-05.002	

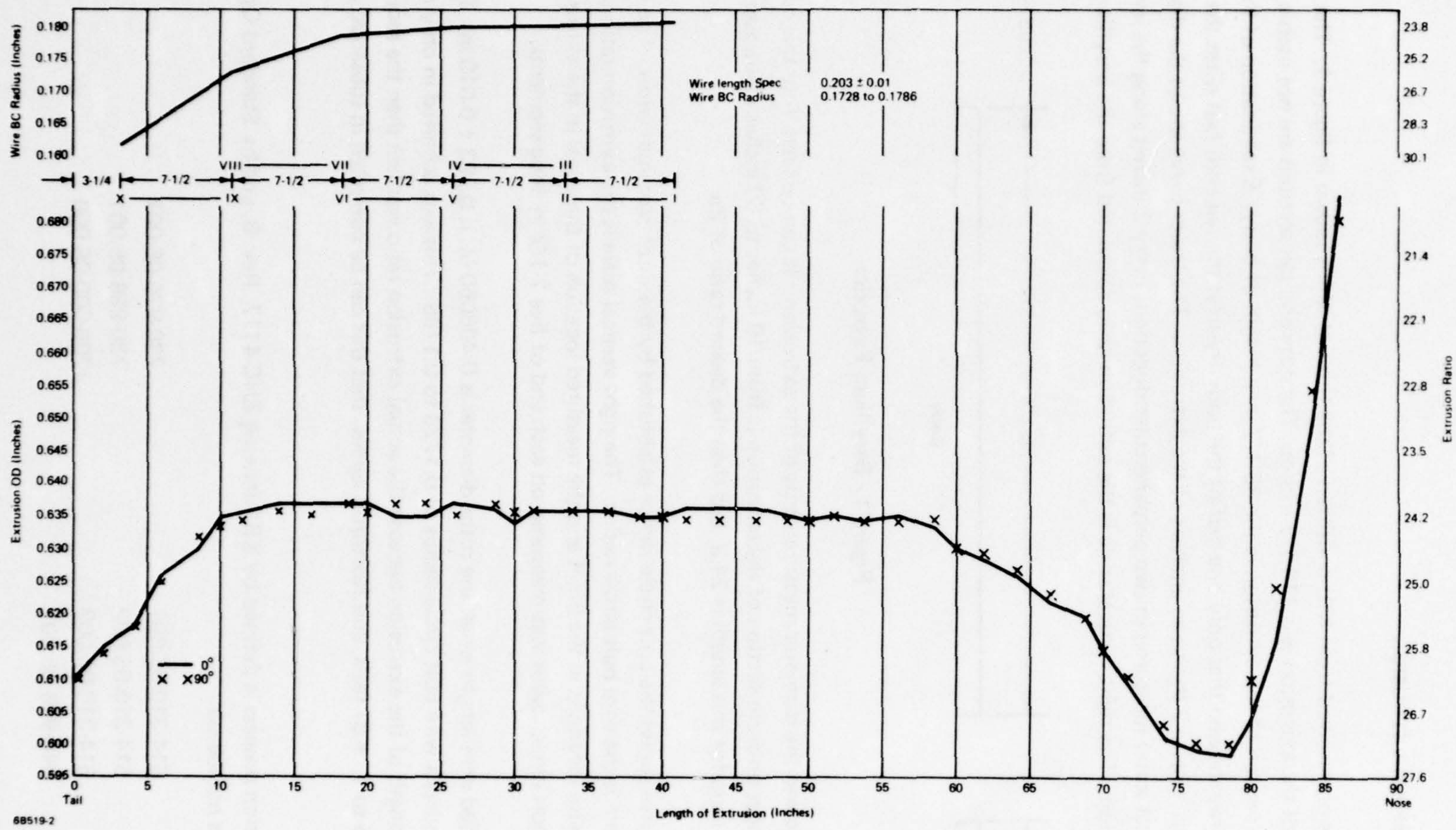


Figure 2. Analysis of KBI Beryllium Billet Extrusion

These documents are included as appendix C.

A review of these documents raised questions on some of the procedures. KBI responded by letter, included as part of Appendix C.

Evaluation tests of the extrusion and the Brush Wellman beryllia discs were conducted by the Charles Stark Draper Laboratory, Cambridge, Massachusetts. The tests conducted were micro-yield strength and modulus of elasticity of two extrusion specimens, longitudinal and radial coefficient of expansion of one beryllium specimen and coefficient of expansion of one beryllium oxide specimen. The test reports are included as appendix D. The test results are as follows:

Micro-yield Strength

Sample	Micro-Yield Strength (2×10^{-6} offset)	Modulus of Elasticity
1	24,500 psi	42.1×10^6 psi
2	16,000 psi	43.0×10^6 psi

Thermal Expansion (95°F to 210°F)

Sample	Coefficient of Thermal Expansion
Beryllium Oxide	2.91×10^{-6} in/in/°F
Beryllium – Longitudinal	7.87×10^{-6} in/in/°F
Beryllium – Radial	6.49×10^{-6} in/in/°F

BERYLLIUM OXIDE

Coors Porcelain Company, Golden, Colorado, was originally selected to supply the beryllium oxide (Be O) discs for the cavities. These discs were 0.770 ± 0.010 dia. by 0.290 ± 0.010 long. The discs as received met all inspection requirements and were processed into cavities. Four cavity assemblies (P/N 12700-302) were manufactured from this material and shipped to Autonetics. During July of 1975, Coors informed PPD that after the end of 1975 they would no longer accept orders for this material (see appendix E). Northrop then selected another second source for the Be O material. The vendor selected was Brush Wellman, Elmore, Ohio. The discs received also met all inspection requirements, but were not processed into cavities due to a change in scope by the Air Force to Northrop's contract.

MATERIAL SPECIFICATIONS

Northrop developed two material specifications under this task to completely define the material and inspection requirements for beryllium and beryllia oxide. These specifications (see appendix B) are:

68848	Material Specification for Standard Grade Beryllium
68849	Material Specification for Dense Beryllia

CONCLUSIONS

Northrop feels that the material and extrusion supplied by KBI needs further evaluation. The low extrusion ratio and the discontinuity of the tantalum wire in the extrusion should be evaluated. Another problem that developed during the fabrication of rotors from this material was exhibited as voids or tear-out which occurred during lapping of the rotors.

Section IV

TASK 3, TOOLING FOR BASELINE CONFIGURATION

INTRODUCTION

As noted in section II, approximately 75 tooling drawings were received as part of the Reprocurement Data Package. A list of these drawings is included in appendix A. Comments on major difficulties and/or inconsistencies in AGRI tooling have been provided in section II.

PPD-DEVELOPED TOOLING

Table I is a list of tooling and fixtures developed by PPD for MESG. Figures 3 through 8 are photographs of several pieces of purchased and PPD-developed equipments.

Table I

PPD—Developed Tooling for MESG

Tool No.	Title
96007	Holding Fixture Roundness Check (M)*
96252	Lapping Fixture, Cavity (M)*
96355	Protective Shield
96359	Rotor Holder
96360	Rotating Fixture, Cavity
96367	Cavity Holder
96370	Cleaning Fixture, Ball, Cavity
96395	Rotor Lapping Machine Modification
96397	Plating and Sputtering Fixtures
96399	Rotor Centering Fixture
96400	Miscellaneous Tooling
96401	Etalon Micrometer
96402	Chrome Target
96403	Gold Target
96404	Interferometer
96421	Cavity O. D. Grinding Fixture
96475	Rotor Holding Fixture, Mikrokator
96494	Proficorder Draft Shield

*(M) = Northrop modified equipment

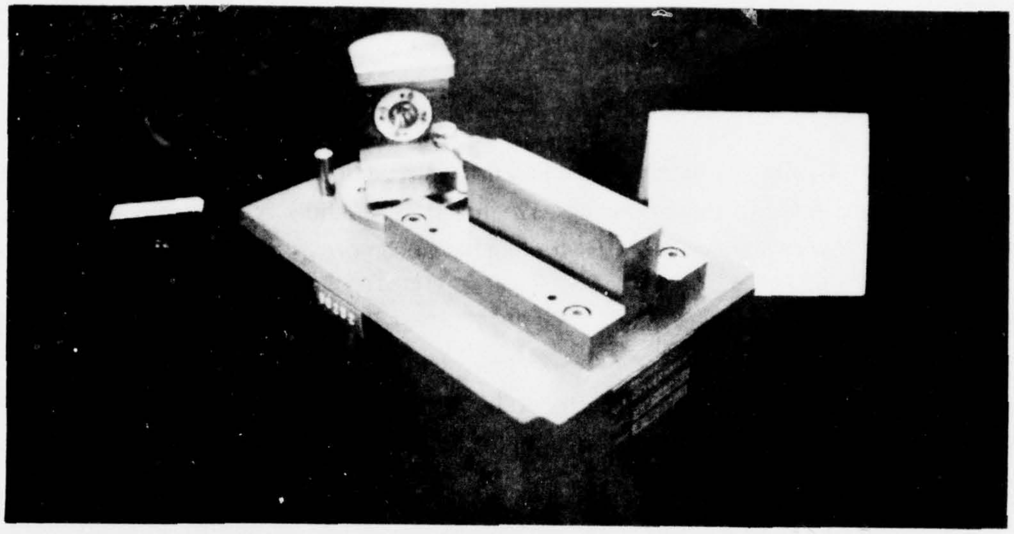


Figure 3. Cavity Slot Lapping Fixture

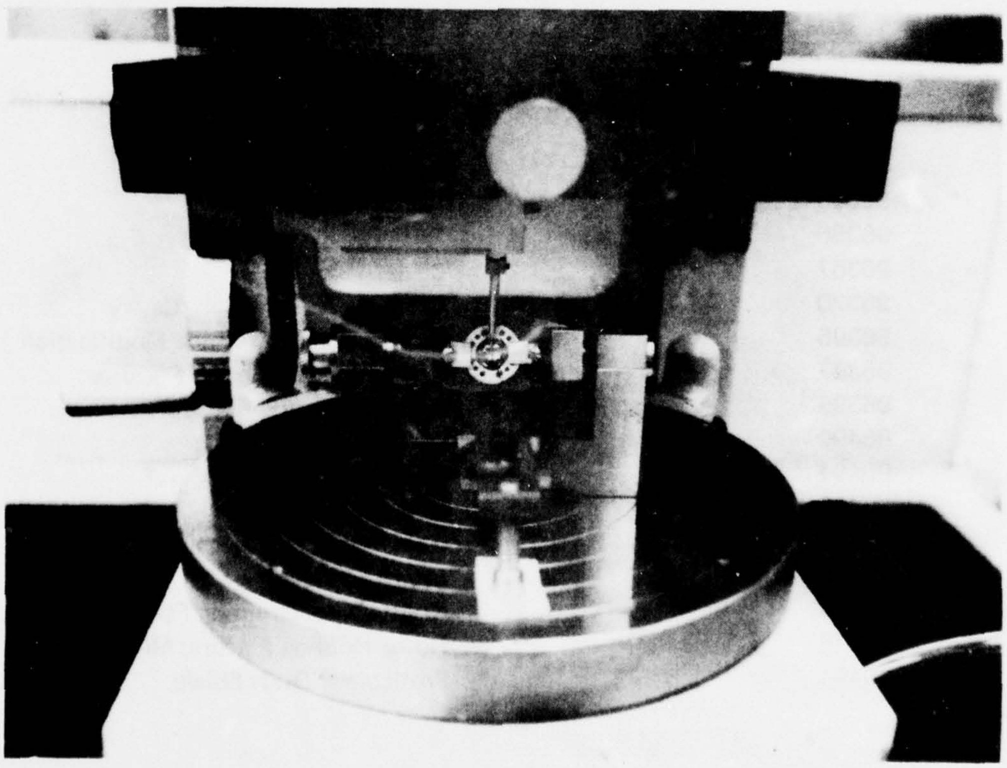


Figure 4. Cavity Roundness Check Fixture

Figure 5. Proficorder with Draft Shield

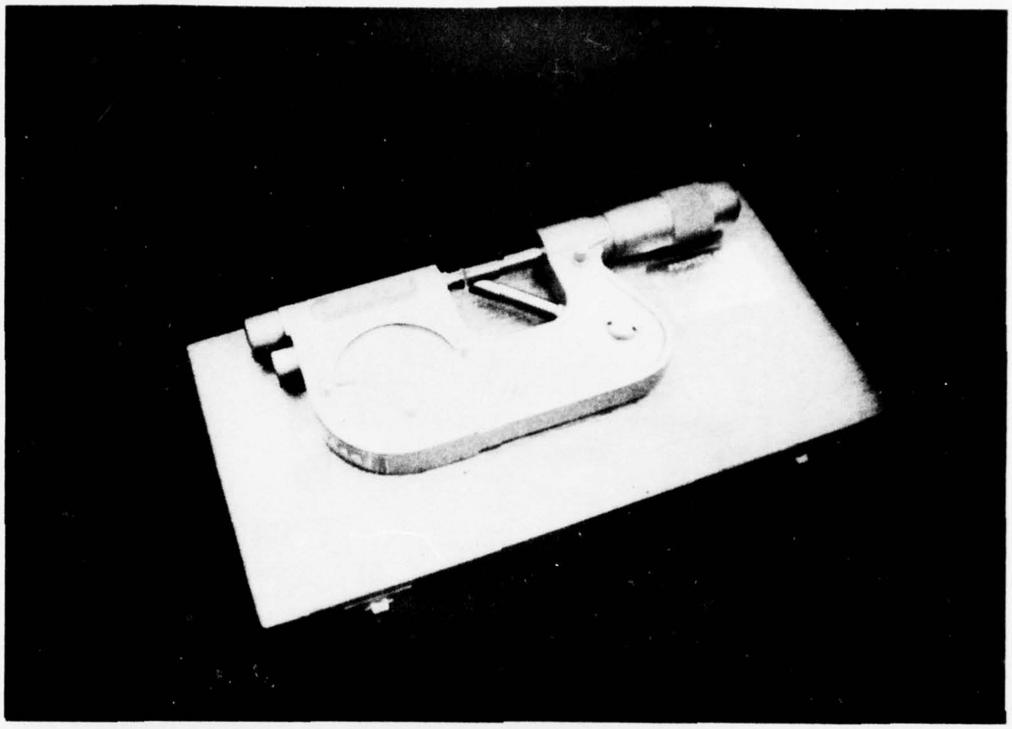


Figure 6. Etalon Micrometer

Figure 7. Cavity Inspection Fixture

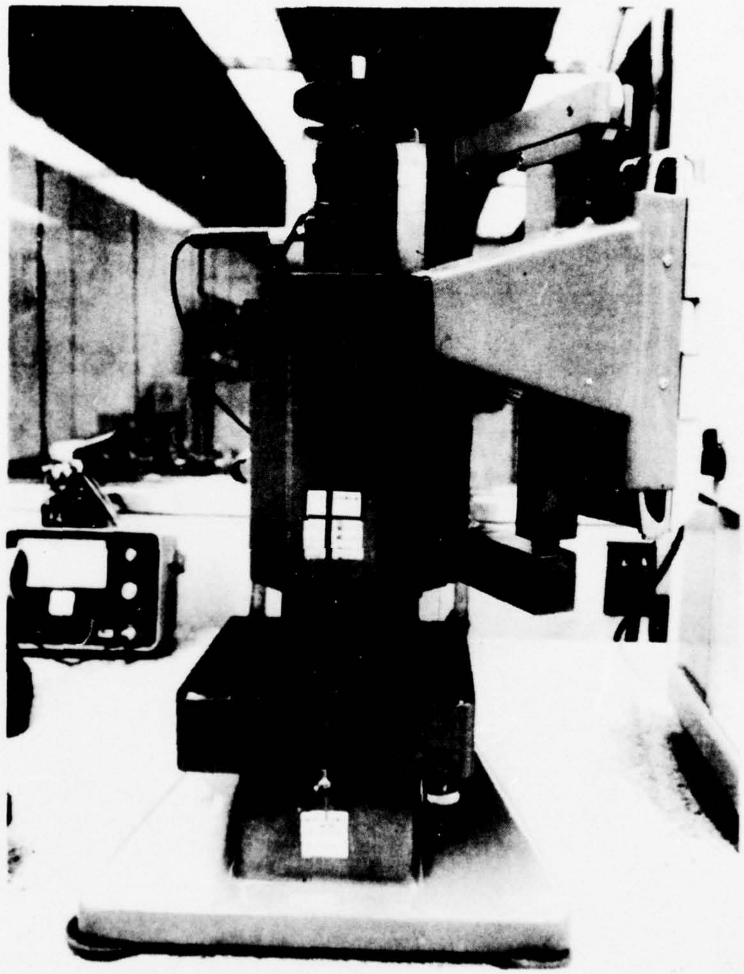


Figure 8. Interferometer

Section V
TASK 4, FABRICATION

INTRODUCTION

This task originally required PPD to build three groups of rotors and cavities using the tooling covered in section IV and according to the data package discussed in section II.

The first group consisted of six rotor and cavity sets fabricated from raw material furnished by the Air Force. The raw material consisted of 12 eloxed rotors and 10 cavity sets in the preplate machined condition. After fabrication, the six rotor and cavity sets were evaluated by the Air Force and the fabrication techniques were approved. The second group of four rotor and cavity sets were then built using raw material obtained by PPD from alternate vendor sources. After approval of this group by the AF, a third group of 10 rotor and cavity sets was scheduled to be built using the alternate raw material. Due to a contract change, this third group was eliminated from the program. Hence, a total of 10 rotor and cavity sets were provided to the AF. Fabrication problems encountered in this task and their solutions are described in this section.

ROTORS

Fabrication

The rotor is a solid beryllium sphere about 0.4 inch in diameter. Embedded in the rotor are three tantalum wires sized and positioned to produce the mass unbalance required by the gyro pickoff. The fabrication cycle for the rotors (per Autonetics Spec AL 70030) begins with the extruded beryllium rod stock containing the tantalum wires. The rod, which is approximately 100 inches long, is cut into usable sections. The following steps are then performed.

1. The sections are X-rayed to determine wire continuity.
2. The rod ends are ground and polished and the wire ends located.
3. A center is located in each rod end based on the center of the wire-bolt circle.
4. The rod OD is then machined concentric to the centers and the rod is ready for electro-discharge machining.

PPD performed these operations on the second source extruded rod with no serious problems.

The next operation performed in fabricating the rotor is electro-discharge machining. This process, in which material is removed by the eroding effect of an electric spark, is used because it produces little or no machining stresses in the work piece. The process is also referred to as eloxing or EDM.

The first series of rotors produced by PPD used material provided by and eloxed by Autonetics. Also provided were several lengths of extruded beryllium rod unsuitable for rotor use, but adequate for developing PPD's eloxing capability prior to receiving the actual second-source extrusion. This material was eloxed on PPD's EDM equipment using the special set up shown in figure 9. Both spindles rotate at specific speeds and directions. In operation, the electrode spindle moves down toward the beryllium rod almost to the point of contact. At this point, a spark is formed in the gap between the rod and electrode. The gap length, which may be in the order of several thousandths of an inch, is servo-controlled by the machine and is adjustable. Other parameters, such as gap voltage and current, duty cycle, and electrode OD and ID, can be controlled to achieve optimum cutting conditions. These parameters were varied until an acceptable rotor (i.e., between 0.410 and 0.412 inch diameter) with good surface finish was produced. Rotor-to-rotor size control was initially good, but in the course of the program, the electrode spindle was damaged resulting in excessive runout (about 0.001 inch). Not enough time was available to permit proper repair and the spindle was used with the runout problem. The rotors that were eloxed at PPD from beryllium obtained from the second source and used to fabricate shippable hardware had diameters that varied a maximum of 0.003 inch from piece to piece. The nominal diameter of these rotors was 0.412 in., and the surface finish was quite good. The spindle has since been repaired and is expected to yield more consistent parts in future operations. After eloxing, the rotors are rough-lapped in a "three-leg lapper" so called because there are three laps in contact with the rotor. This device is shown in figure 10. Successively finer lapping grits are used to bring the rotor to a diameter of 0.406050 at which point it is removed from the lapping machine, cleaned, and examined under 20 X to determine the surface finish quality. If excessive pits or scratches too deep to be removed in later operations are present, the rotor is rejected. If it is acceptable, the wire ends are located and marked with ink and the rotor is X-rayed to determine the wire lengths. Locating the wire ends is a tricky chore requiring a skilled operator but must be done in order to provide a means of orienting the rotor during X-ray. This is achieved by positioning the rotor so that the wires are horizontal as indicated by the ink dots. The X-ray is recorded on Polaroid film and the wire lengths read using a toolmaker's microscope. For the X-ray equipment used by PPD, a correction factor must be applied to the measured wire length. This is caused by divergence of the X-rays and amounts to about 1.5% or 0.003 inch. If for some reason X-rays are obtained at a different diameter than 0.406050, the wire lengths obtained must be corrected to what they would be at this diameter in order to have a common basis for comparison.

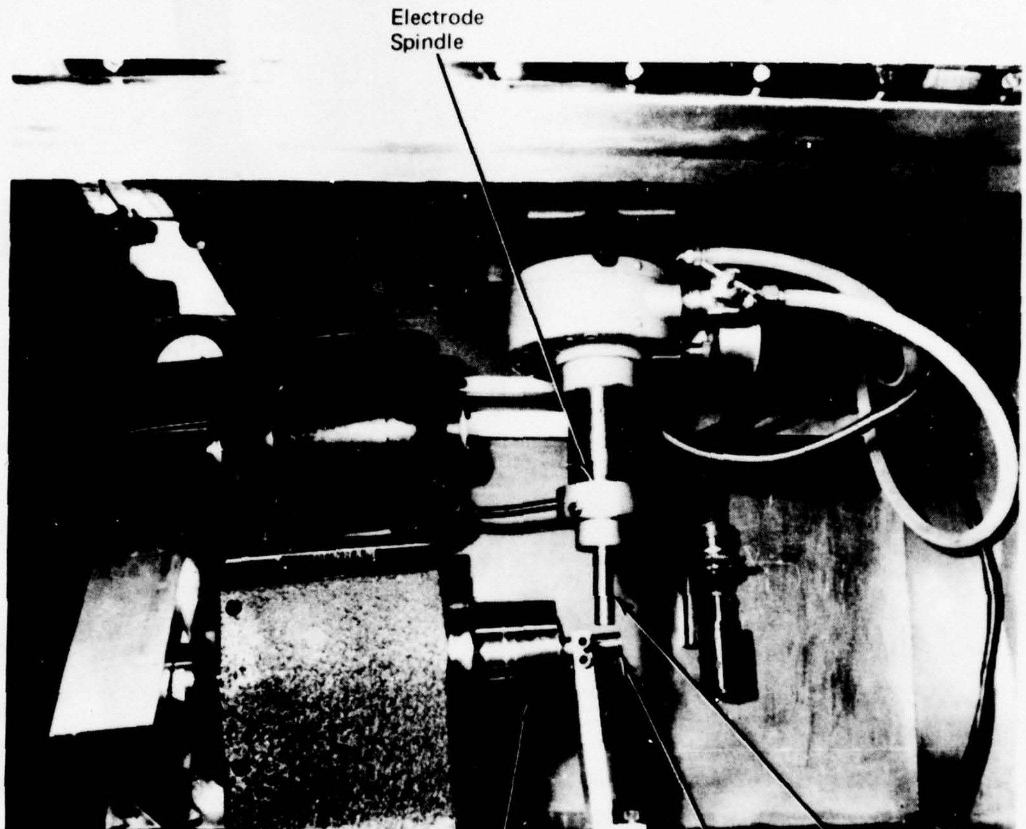


Figure 9. Electro-Discharge Machining (EDM) Setup

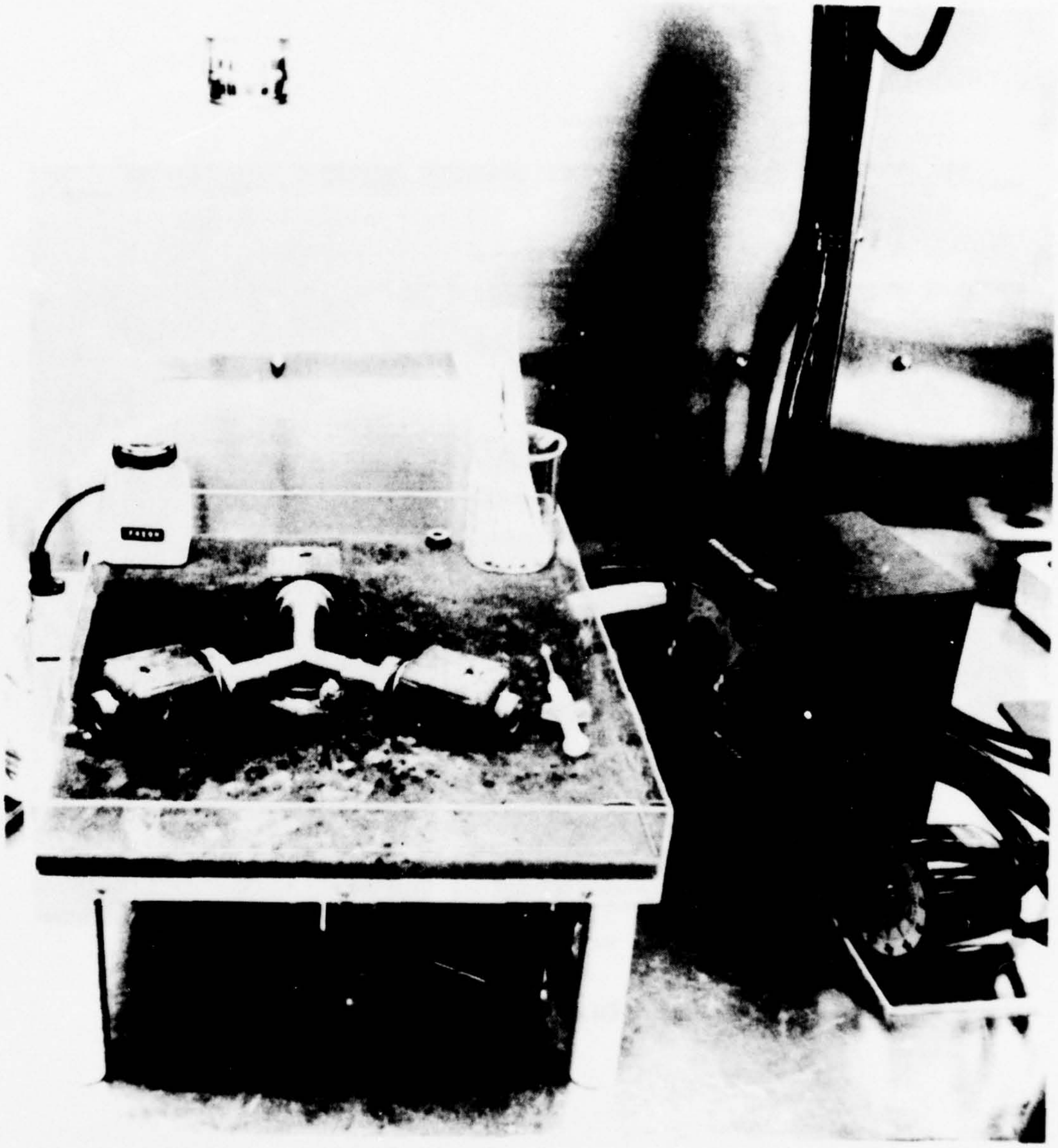


Figure 10. Three-Leg Rotor Lap

Cold lapping in the "two leg lapper' follows X-ray. This machine (see figure 11) is used to further reduce the rotor size. When the diameter is 0.405750 in., the lapping temperature is increased from room temperature to 147° F at which the remaining stock removal is performed. The rotor is lapped round at this temperature but because of the anisotropic temperature coefficient, is out of round by approximately 30 microinches when returned to room temperature. At this point the rotor is finish pitch-lapped in the three-leg lap machine to develop an optical finish; it is then cleaned and packaged.

Measurements

Size measurements are performed on the rotor at various times during the build cycle. The critical measurements are obtained just prior to final pitch lap and consist of size (diameter) and roundness. Rotor surface finish, although critical to ESG operation, is not specified quantitatively, but rather is arrived at through a subjective visual inspection under a microscope. Surface finish quality is designated as "good" "very good", etc., and depends on the skill and experience of the observer for legitimate results. Inspection records do not show surface finish quality.

Rotor size measurements consist of measuring the maximum and minimum diameters during final pitch lapping. This is done several times until a stock removal rate is established. When the rotor size is 0.405580 ± 5μ in. major and 0.405550 ± 5μ in. minor diameter, no further measurements are made. The final size is determined by lapping for a known period of time and, using the stock removal rate obtained previously, computing the final size. Ten μ in. of material are removed in this operation at which point no further lapping is performed.

A comparison of the rotor sizes obtained by PPD with those obtained by Autonetics' Metrology Department is given in table II.

Agreement between PPD and AGRI for the first 7 rotors (Z series) varies from poor to excellent with no apparent trend or offset in the data. One rotor, Z16, shows the largest disagreement with both the maximum and minimum diameter sizes being below specification value. This measurement could possibly be in error. If some of the AGRI data was not in fact obtained at 68° F, there would be less variation in the results. The second group of 4 rotors (NA series) is expected to show improved correlation as techniques have been refined.

Rotor Yield

Rotor yield was significantly affected by problems associated with material. On the first group of six rotors shipped for twelve started, 17% were rejected for problems related to material. These problems included voids and inclusions in the material that could not be removed during subsequent lapping operations.

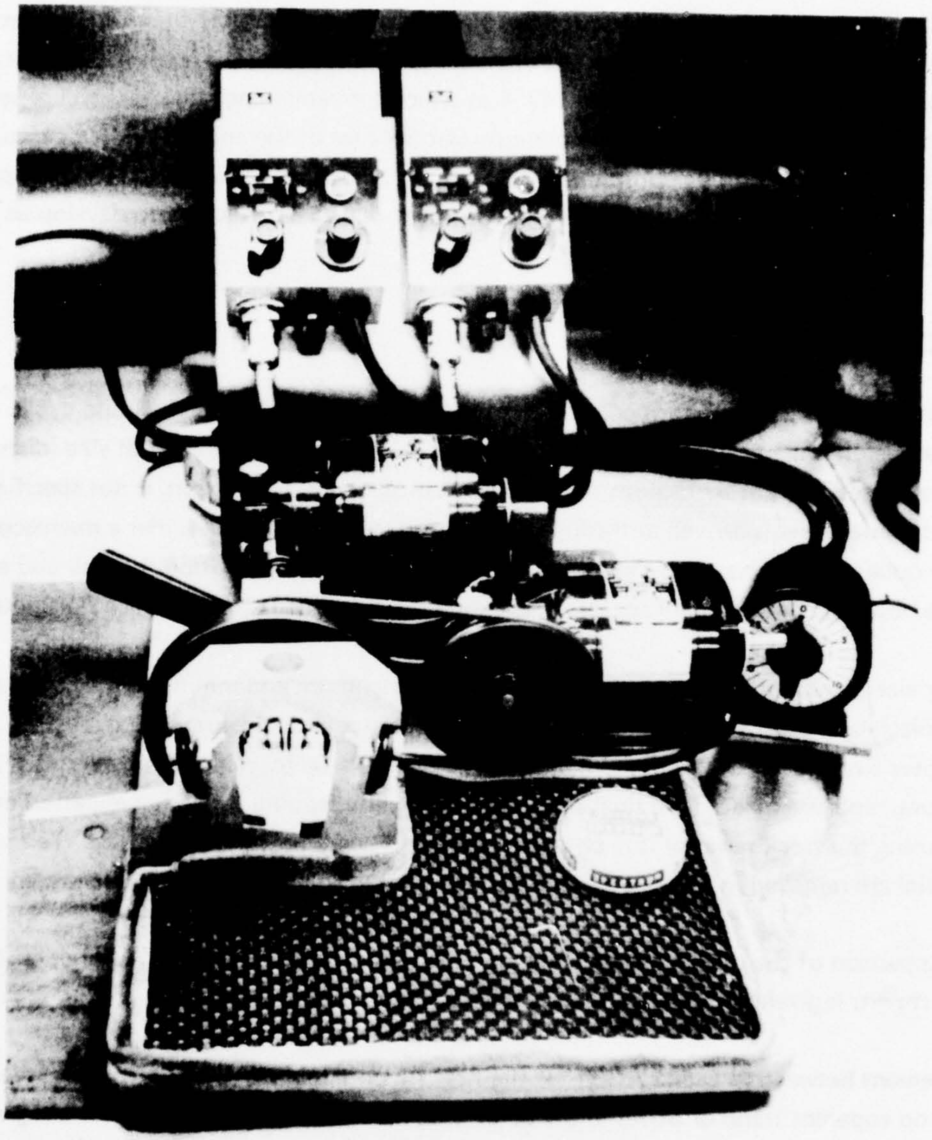


Figure 11. Two-Leg Cold Rotor Lap

On the rotors fabricated from material supplied and extruded by KBI, the reject rate for material-related causes was 36%, or about double the AF-supplied material rate, the major problems being tear-out during lapping, inclusions and voids. There appears to be a major difference in these materials, probably due to the manner in which they were processed. The exact causes are not presently known, but should be investigated and corrected for future program use.

Conclusions

The procedures presented in Autonetics' Specification AL70030 for lapping MESG rotors were followed closely during the program and were found to be adequate as presented. The actual execution of the various operations requires considerable skill and experience on the part of the operator for successful results. This is especially true in regard to the final lapping and measurement operations where loss of random motion in the lapping machine or improper measurement technique can result in a scrap rotor.

Table 5-1

PPD and AGRI Rotor Diameter Measurements

Rotor S/N	PPD Max.	PPD Min.	Δ	AGRI Max.	AGRI Min.	Δ	Max Dia. Δ	Min Dia. Δ
Z13	0.405568	0.405540	28	0.405560	0.405532	28	– 8	– 8
Z16	0.405559	0.405531	28	0.405542	0.405522	20	– 17	– 9
Z18	0.405562	0.405535	27	0.405565	0.405549	16	+ 3	+14
Z20	0.405566	0.405539	27	0.405560	0.405535	25	– 6	– 4
Z21	0.405565	0.405535	30	0.405565	0.405540	25	0	+ 4
Z22	0.405568	0.405540	28	0.405565	0.405540	25	– 3	0
Z23	0.405571	0.405545	26	0.405563	0.405532	31	– 8	– 13
NA – 11	0.405570	0.405541	29	0.405566	0.405538	28	– 4	– 3
NA – 14	0.405565	0.405540	26	0.405567	0.405537	30	+ 2	– 3
NA – 16	0.405568	0.405538	30	0.405566	0.405538	28	– 2	0
NA – 22	0.405573	0.405547	26	0.405572	0.405546	26	– 1	– 1

Notes:

Δ = Max. – Min. Dia.

Δ Max. Dia. = AGRI max. – PPD Max.

Δ Min. Dia. = AGRI Min. – PPD Min.

All PPD measurements corrected to 68°F

All AGRI measurements are believed to be corrected to 68°F

Spec. value

Max. dia. 0.405570 ± 10 micro in.
Min. dia. 0.405540 ± 10 micro in.

CAVITIES

Fabrication

The cavities were processed according to AGRI Spec. AL70032. The controlling drawings for the cavities were 12698, 12699 and 12700. Several problems were encountered during fabrication of the cavities in the areas of sputtering, slot-lapping and measurement.

The fabrication cycle for the cavities begins with the beryllia blank which is purchased as a disk (0.770-inch diameter by 0.290-inch thick). The blanks are examined for uniformity, cracks, surface defects and properties. They are then machined to shape and ready for lapping of the equator face and cavity.

The cavities are lapped to remove minimal material to improve the sphericity of the cavity and the flatness and location of the equator. Next the cavities are cleaned ultrasonically in a mixture of acetone, toluene and freon; washed in aqua regia at 150°F; rinsed in deionized water and finally baked at 1600°F. The parts are then sputtered; first with chromium on the beryllia to produce a continuous film, and then with gold on top of the chromium to provide a film approximately 50 microinches thick.

Masks are used on the cavities to limit the material being sputtered on the cavity and to produce a defined pattern on the equator. The cavities then receive a Niculoy plate on top of the gold and are ready for final lapping (per Autonetics Spec AL70032).

The equator face is lapped on a ceramic lapping plate first using 38-900 compound to remove the excess Niculoy. This is followed by lapping with No. ½ diamond compound to achieve flatness.

The piece is then rough-lapped using a hand-held cavity lapper and No. 6 diamond compound with Naptha as the vehicle. This operation brings the cavity to 0.40525 in.dia. The equator is lapped to this diameter. The rough lap process is continued using No. 3 diamond compound and Naptha and the cavity size brought to 0.40615 in. dia. The equator is lapped again to match the diameter.

Next, the cavity is lapped, using 38-900 compound, to remove plating from the cavity chamfer. After the chamfer is completed and inspected, the slots are lapped in the hemisphere to form the 4 plates. The slots are then inspected for symmetry, width, depth, cleanliness and cavity plate separation.

The cavity is now ready for final lapping of equator and hemisphere. The hemisphere is lapped to final size of 0.406250 ± 0.000010 inch diameter with No. 3 diamond compound and Naptha.

The equator is lapped to locate the center of the spherical diameter outside the part by 0.000005 ± 0.000003 in.

The cavity halves are assembled with the proper alignment rotor, the parts are scribed, and then ground to make the outside diameter of the 2 cavity halves concentric. The cavities are then disassembled and final measurements of size and roundness are made. At this point the cavities are finish pitch-lapped, then cleaned and packaged.

Sputtering

The sputtering problem manifested itself as inadequate adhesion between the chrome and gold sputtered material, resulting in lifting of the plating at the slot edges and near the equator. These cavities had been sputtered at PPD in a two-step operation in which the chrome target (used to deposit a layer of chrome on the cavity) is replaced by the gold target for depositing gold. Because of the type of equipment available at PPD, it was necessary to break the vacuum in the deposition chamber, thereby exposing the newly deposited chrome to the atmosphere and possible contamination. Concern was expressed by PPD's M&P Group that this could result in poor adhesion. However, when samples were tested per AGRI instructions, tensile strengths measured 3300 psi, exceeding the AGRI requirement of 2000 psi. Five cavity halves sputtered as described above were processed and lapped. Three failed for plating lifting indicating a serious problem existed, quite probably caused by the two-step sputtering process. Accordingly, an outside vendor with equipment that permitted one-step sputtering was found and cavities and samples processed. When tested, the samples exhibited a tensile strength of 5400 psi. The cavities were plated and lapped with no lifting problems, thereby demonstrating the necessity of using one-step sputtering. PPD has recently purchased new equipment capable of one-step sputtering and can now perform this operation in-house.

Slot-Lapping

The slots, which separate the cavity hemispheres into four equal parts, are cut into the plating just prior to finish lapping. On the first group of six cavity sets delivered, AGRI expressed concern about "dirty slots" which might indicate excessive amounts of plating material left in the slots. This could result in a lowering of resistance across the plates and degradation of gyro performance. These slots were lapped with aluminum oxide compound and Ferro-Tic laps. The second group of four cavities was lapped with Carboloy laps, a material used by AGRI which appeared to produce cleaner cuts on AGRI-made cavities. These laps seemed to produce slightly better looking slots. A requirement to check resistance between the plates was added for this group and when measured, all cavities exceeded the 1000 megohms resistance specified. None of the first group of cavities was rejected by AGRI for interplate resistance. Therefore, it appears

that although cavities produced by PPD do not have slots as clean as those produced by AGRI, they do meet drawing requirements and are usable parts.

Measurements

There are two critical measurements for the cavity halves: 1) the spherical diameter, and 2) the equator location. These measurements are made with comparators referencing a standard cavity calibrated by Autonetics.

Data obtained on the cavities at PPD and at AGRI is given in table III. Shown is the cavity set serial number, spherical diameter and equator location as measured by PPD and AGRI, and the difference of the measured diameter. Information on temperature at which measurements were made is also given where known.

Inspection of table III shows that cavity S/N's 1, 2, and 3 were measured by AGRI to be larger than measured at PPD. The remainder of the cavity sets show diameter agreement within reasonable limits. The discrepancy in the first three sets is believed to be caused by differences in the temperature at which the parts are measured at PPD and AGRI, and differences in the temperature coefficients of BeO used by PPD and AGRI. PPD has used 2.65×10^{-6} in/in/°F as the temperature coefficient of BeO throughout the program, while AGRI has used 3.7×10^{-6} in/in/°F.

Measurements of temperature coefficient made on Brush Wellman BeO indicate that 2.8×10^{-6} in/in/°F is the correct value about room temperature. Starting with set NA0007, AGRI used this value to correct diameter size to 68° F, resulting in excellent agreement between PPD and AGRI for this set and NA0008.

An additional reason for lack of agreement between PPD and AGRI for the first series of cavities was lack of consistency in the calibrated size of the cavity master N-7. Several size values were obtained from AGRI for this master before consistent data was achieved.

Equator location correlation has been good except for the first three cavity halves shipped. This discrepancy was caused by a misinterpretation of the drawing callout as to whether the center of the hemisphere is located inside or outside of the part. The correct location is outside the part and by convention is given a negative sign.

Conclusion

PPD feels all problems involved in providing second source fabrication capability for MESG cavities have been solved. With PPD's procurement of one-step sputtering equipment, no further adhesion problems are expected. The cavity slots produced by PPD have met the requirements of the drawings and size, and equator location measurements made by PPD on the last cavity sets shipped have shown excellent agreement with AGRI.

Table III

PPD and AGRI Cavity Measurements

		PPD			AGRI					
Cavity Half S/N		Spherical Dia.		Equator Location	Meas. Temp. AGRI	Spherical Dia.		Equator Location	△Dia.	△Equ.
N0001 – 1	N1	0.406250	–	0.000004	?	0.406259	+	0.000006	+ 9	+10
N0001 – 3	N1	0.406250	–	0.000004	?	0.406259	+	0.000006	+ 9	+10
N0002 – 1	N2	0.406250	–	0.000005	?	0.406255	+	0.000002	+ 5	+ 7
N0002 – 3	N2	0.406250	–	0.000005	?	0.406260	–	0.000004	+10	+ 1
N0003 – 1	N3	0.406258	–	0.000002	82°F	0.406264	–	0.000004	+ 6	– 2
N0003 – 3	N3	0.406258	–	0.000002	82°F	0.406264	–	0.000001	+ 6	+ 1
N0004 – 1	N4	0.406248	–	0.000003	82°F	0.406250	–	0.000003	+ 2	0
N0004 – 3	N4	0.406248	–	0.000003	82°F	0.406252	–	0.000003	+ 4	0
N0005 – 1	N5	0.406245	–	0.000005	82°F	0.406246	–	0.000004	+ 1	+ 1
N0005 – 3	N5	0.406245	–	0.000003	82°F	0.406246	–	0.000001	+ 1	+ 2
N0006 – 1	N6	0.406245	–	0.000003	82°F	0.406247	–	0.000001	+ 2	+ 2
N0006 – 3	N6	0.406243	–	0.000004	82°F	0.406246	–	0.000002	+ 3	+ 2
NA0007 – 1	NA1	0.406254	–	0.000006	77°F	0.406251 *	–	0.000008	– 3	– 2
NA0007 – 3	NA9	0.406254	–	0.000006	77°F	0.406252 *	–	0.000006	– 2	0
NA0008 – 1	NA4	0.406246	–	0.000006	77°F	0.406246 *	–	0.000005	0	+ 1
NA0008 – 3	NA12	0.406246	–	0.000005	77°F	0.406245 *	–	0.000004	– 1	+ 1
NA009 – 1	NA2	0.406258	–	0.000005	?	0.406256	–	0.000004	– 2	+ 1
NA009 – 3	NA10	0.406258	–	0.000005	?	0.406252	–	0.000000	– 6	+ 5
NA0010 – 1	NA3	0.406251	–	0.000004	?	0.406249	–	0.000003	– 2	+ 1
NA0010 – 3	NA11	0.406250	–	0.000004	?	0.406248	–	0.000007	– 2	– 3

Notes: △ = AGRI measurement - PPD measurement

Dimensions in inches except △ Dia. & △ Equ. is 10^{-6} inches
On Equator Locations, + means Equator located inside the part.

All PPD measurements made between 68 and 73°F and corrected to 68°F
<u>Spec. Value</u>

Dia. 0.406250 ± 10 microin.
Equator - 0.000005 ± 3 microin.

*Corrected to 68°F at 2.8μ in/in/°F

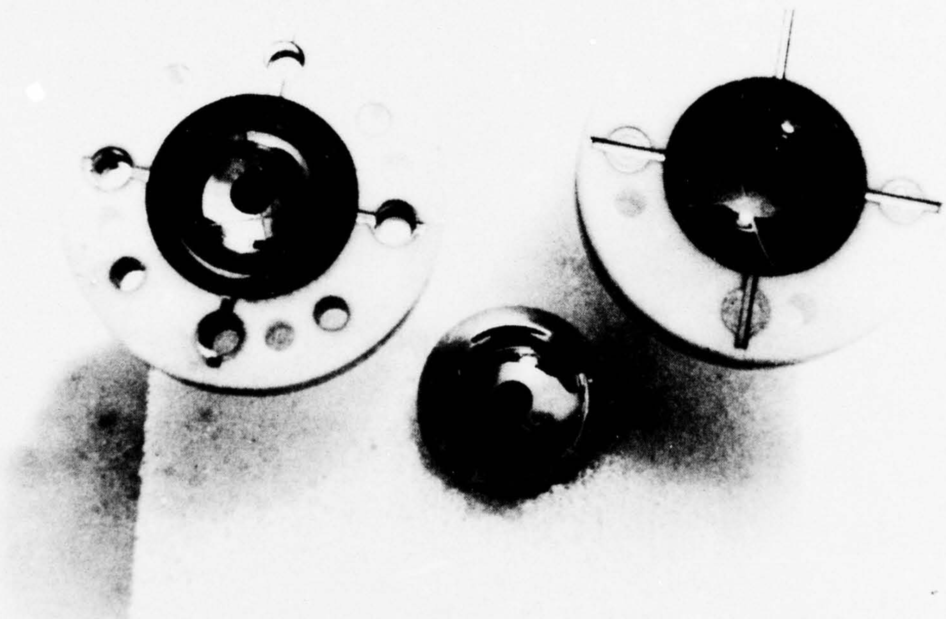


Figure 12. Rotor and Cavity Set

Section VI

TASK 5, PRODUCT IMPROVEMENT

INTRODUCTION

The purpose of this task was to investigate alternate rotor and cavity production techniques to effect reduced costs. Areas of investigation included automatic cavity machining, slot lap material, microinch measurement of rotors, rotor stock removal techniques, and improved lapping techniques.

After preliminary investigation of all these areas, PPD selected rotor stock removal techniques as its major effort because of its potential to achieve the most cost effective results. (The labor involved in fabricating one MESG rotor is very high.)

Stock Removal

PPD investigated several different methods to obtain stock removal at minimal labor cost. Chemical etching was considered, but such etching is not feasible because the beryllium and tantalum in the rotor do not etch at the same rate. Another method investigated for low cost stock removal was multi-lapping techniques. PPD did some preliminary investigation on designing new lapping machines to accommodate two and three rotors at the same time. This approach does seem feasible; however, the machine fabrication cost would have been beyond the scope of this program.

The electrical discharge machining of the extruded beryllium into rotors was evaluated and PPD found that the process could be controlled for size and surface finish to a smaller diameter than specified. Autonetics specified in specification AL 70030 (revised 12/11/74), that "Rotors must not be smaller than 0.418 inches in diameter following elox operation." PPD has determined that this size can be reduced by 0.008 in., thereby saving the labor involved to lap rotors this amount. Autonetics has concurred and revised its specification on 4/30/75 to read "smaller than 0.410 in." An estimated 27% of total lapping labor is saved by reducing the rotor size from 0.418 in. dia. to 0.410 in. dia.

TUMBLING TECHNIQUES

PPD concentrated its remaining effort on stock removal to an investigation of tumbling techniques. PPD engineers visited several metal finishing companies and supplied them with rotors to determine what could be accomplished by different tumbling methods. PPD also asked each company to determine stock removal rate, media, compounds and instruments used. This was accomplished and the results were very encouraging.

PPD pursued several parallel paths during this task. Companies expert in the field of metal finishing and stock removal were consulted. They included United States Products for both fine and aggresive compounds; Norton Company for advice on different types of media for the MESG application; Fortune Metal Finishing for investigation of and advice on different instrumentation.

PPD then purchased two different types of stock removal equipment; a barrel tumbler and a vibration tumbler. PPD also purchased several different types of media and stock removal compounds ranging from fine polishing compounds to coarse aggressive compounds. The media consisted of various shapes such as stars, triangles, random, round and oblate geometries made from different materials.

PPD also started an effort going in its own machine shop to remove metal and to determine the best media and compounds to be used. After trying many different types of media and compounds, PPD decided that it would be necessary to remove approximately 30 microinches of metal per hour in order for this approach to be cost effective. This will bring the rotor from EDM size to the point where it is ready to X-ray in about 1 week.

The following paragraphs describe the principles of barrel and vibrating tumbling.

Barrel Tumbling

The basic principle of barrel finishing is the removal of stock by the abrasive action of a rotating mass of material. The abrasive action is caused by a sliding movement of the upper layer of the work load relative to the barrel, and the direction in which it rotates. The parts or work load move upward with the rotation to a point where gravity overcomes the tendency of the work load to hold together. At this point the parts and media cascaded toward the lowest point of the barrel. The abrading action takes place within and directly under the sliding top layer. There is also some vertical abrasion which takes place due to continuous settling of the load. Height and thickness of the top layer and the extent of abrasive action varies with the speed and diameter of the barrel. This should be controlled to produce the thickest sliding layer without excessive cascading action which would cause damage such as pitting and impingement. The faster the barrel rotates, the greater the stock removal (up to the point where centrifugal force exceeds the sliding action caused by gravity). Impingement takes place at the bottom of the slide, before the parts are carried under the media mass.

Vibratory Finishing

The basic principle of vibratory finishing is stock removal by the vibratory action of abrasives against parts. The vibration of the barrel causes a rubbing action between the media, parts and compound. This action rectifies the vibration and produces a tumbling action. The result is that relative motion exists between parts and media in every part of the barrel. The size and shape of the media, amount of abrasive compound and amount of liquid carrier are very critical in determining the stock removal rate.

Comparison of Tumbling Methods

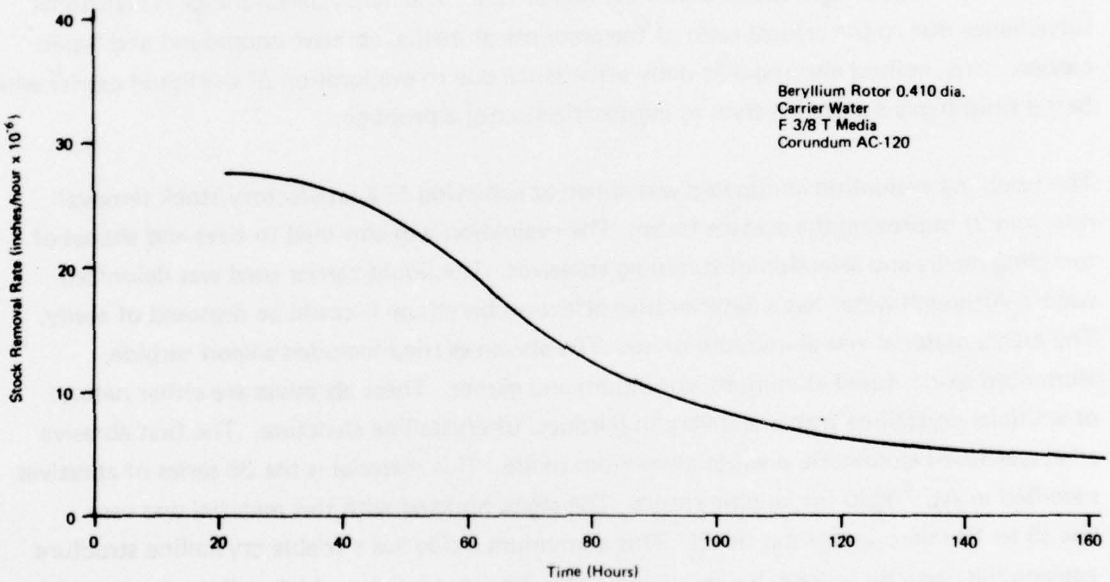
Although vibratory finishing removes stock at a slightly higher rate than barrel finishing, this method has disadvantages which offset the higher rate. The major disadvantage is additional surveillance due to the critical ratio of the amounts of media, abrasive compound and liquid carrier. This method also requires daily attendance due to evaporation of the liquid carrier while barrel finishing is a closed system so evaporation is not a problem.

The tumbling evaluation conducted was aimed at achieving 1) a satisfactory stock removal rate, and 2) improving the surface finish. The evaluation was confined to sizes and shapes of tumbling media and selection of tumbling abrasives. The liquid carrier used was deionized water. Although water has a deteriorative effect on beryllium it could be disposed of easily. The media material was aluminium oxide. The abrasives tried included silicon carbide, aluminum oxide, fused aluminum, corundum and garnet. These abrasives are either natural or artificial crystalline forces and vary in hardness of crystalline structure. The first abrasive tried was fused aluminum, a white aluminium oxide. This material is the 38 series of abrasives specified in AL 70030 for lapping rotors. The stock removal with this material was very low (5 to 10 micro-inches per hour). This aluminium oxide has a friable crystalline structure causing the particles to keep breaking down into smaller particles which will produce a good surface finish but ineffectual stock removal. Additional trials with other abrasives and media shapes resulted in the following selection of materials. The media is a ceramic oblique equilateral triangle 0.38 in. per side by 0.20 thick (Wisconsin Porcelin Company F3/8T). The abrasive is Corundum AC - 120 (manufactured by the United States Products Company) which has a softer crystalline structure than aluminum oxide. Moreover, the crystal shape produces much better cutting action, hence faster stock removal.

Figure 13 shows typical stock removal rate on an MESG rotor of 0.410 in. diameter. The stock removal starts at 28 microinches per hour and decreases to about one-half that rate in 70 hours. This shows that the abrasive has broken down to the point where it is worn out

and should be replaced. The stock removal rate can be increased by about a factor of four by optimizing the speed of the tumbling barrel and its diameter. The life of the abrasive can probably be increased by changing the media from ceramic to a softer material. The fluid carrier could be a liquid such as Varsol or Soddard Solvent.

The tumbling process shows considerable promise as a cost effective method to replace the hand lapping procedure presently being used. Further evaluation work is required to completely define this operation and determine the maximum material that can be removed before lapping is required. An estimated 38% of the total lapping labor could be saved by reducing the rotor size from 0.410 in. diameter to 0.406 in. diameter by the tumbling process. The 0.406 in. diameter is the point where hot lapping starts.



6B519-8

Figure 13. Stock Removal Rate

Section VII

RELIABILITY AND MAINTAINABILITY

RELIABILITY

The rotor/cavity subassembly is the most critical item within the MESG instrument. The fine finishes and extreme tolerances in a difficult geometrical configuration demand an inordinate amount of attention during the fabrication cycle. As automated tools and machines do not yet exist to produce these parts, a high degree of interface becomes necessary between the parts, tools, and operator. Of these three, the operator is the least reliable element, yet remains the most important because of his versatility and decision-making capability. The tools, fixtures, and processes are as reliable as is possible at this stage (state-of-the-art) in the life of the gyro.

Rotors

There are many causes affecting the fabrication yield of rotors. No specific tool, fixture, or process can be charged as being individually responsible for this yield, because rotor quality is not established until the final stages of rotor fabrication. Should the rejection cause be material-related, only the grossest of imperfections can be detected prior to the rotor reaching a high level of polish. At this time, material flaws, too small to be seen by X-ray and easily hidden by electrical discharge machining, are exposed.

Perhaps the second highest cause for rejection is a scratch or gouge too deep for removal during the final stages of lapping. Fixturing and measuring equipment has been chosen with prevention of damage in mind. In the instances where the rotor comes into contact with hard materials, the surface finish of these materials and/or the contact pressure, are held to a level to prevent damage to the parts. In other instances, the material in contact is chosen for softness. In both cases cleanliness is paramount since a hard particle, minute in size, can cause sufficient damage to destroy the usefulness of a part.

The most important fabrication technique is that of lapping. It is here that the skill of the operator is applied. The operator, in charging the lap, establishing lap pressure, and assessing the effectiveness of the lapping operation, provides the judgement factor that cannot be economically built into the tools. While the lapping compounds are closely controlled for size, they do offer the potential of destructive damage should an oversized particle appear in the compound. The total effectiveness of this operation depends upon the capability, training, and most importantly, the motivation of the operator.

Cavities

The causes affecting cavity yield are also numerous. The largest fallout occurred in sputtering and plating closely followed by slot-lapping. A narrow-wall carboloy lap, instead of Ferro-Tic, resolved the problem of plating lifting at this operation. The area of sputtering and plating has received considerable attention and should show improved yield on future orders. A full discussion of cavity fabrication problems is provided in section 5.

Tooling and Instrumentation

Reliability of these items was improved by a number of means. Etalon micrometers have carbide anvils to increase life and permit relapping if required. Master cavities have been made of beryllia, secondary standards of tungsten carbide. Sheffield Accutrons were obtained with ruby sensor tips and ceramic anvils for long life and stability. Air buffered electronic instruments replaced mechanical contact type Mikrocators. Ceramic lapping plates are used for their characteristics of easy cleaning, non-embedding surfaces, and ability to retain flatness, thereby allowing use with different compounds without requiring grinding as a cleaning operation.

MAINTAINABILITY

Maintainability of the tools and fixtures is relatively easy. The most complicated maintenance task is that related to the relapping of anvils or flat plates. The critical natures of the rotors and cavities and operations require frequent maintenance to preserve the reliability of the operation. Bearings of the two and three-leg lapping machines are (and must be) lubricated between fabrication lots. At the same time, drive belts, and laps, must be inspected and replaced or reconditioned. Scheduled for inspection at less frequent intervals are the flat plates and inspection anvils. As no high rate of production has yet taken place, a rigid schedule of maintenance has not been established. Table IV summarizes the Reliability/Maintainability factors.

Table IV
Summary of Reliability/Maintainability Factors

Tool	Reliability	Maintainability
Holding Fixture Roundness Check	High	Low Incidence
Lapping Fixture Cavity	High	Low Incidence
Rotor Holder	Moderately Low	Unnecessary
Rotating Fixture, Cavity	Moderately High	Low Incidence
Cavity Holder	Moderately High	Low Incidence
Cleaning Fixtures, Rotors and Cavities	Moderately High	Moderately Low
Rotor Lapping Machine (Hot Lapper)	Moderate	High Maintenance Required
Plating and Sputtering Fixtures	Moderately Low	High Maintenance Required
Rotor Centering Fixture	Not Used on This Order, Therefore Not Evaluated	
Etalon Micrometer	Moderately Low	High Maintenance Required
Chrome and Gold Targets	High	Low Incidence
Interferometer	High	Low Incidence
Cavity O.D. Grind Fixture	Moderately High	Low Incidence
3 Leg Lap	Moderate	High Maintenance Required
2 Leg Cold Lap	Moderate	High Maintenance Required
Cavity Automatic Lapper	Moderate	Moderate
Cavity Hand-held Lap	Moderate	Moderate
Rotary Proficorder	High	High Maintenance Required
Rotor Measuring Instruments	Extremely High	Moderately High
Cavity Measuring Instruments	Moderate	High Incidence

Section VIII
SYSTEM SAFETY

INTRODUCTION

Item 2.2 of the SOW required PPD to perform a preliminary system safety analysis with the objective of minimizing unintentional catastrophic failure and physical harm to bystanders. Since over-all system responsibility does not rest with PPD, this portion of the safety requirement is not applicable. However, because of the hazards associated with machining beryllium and beryllia, certain safety precautions were required to protect personnel and these efforts are reported in this section. In addition, due to the extremely fragile nature of the parts being fabricated, numerous precautions were taken in designing the work areas and tooling and in handling the parts.

PERSONNEL SAFETY

If inhaled in high concentrations, beryllium and beryllium oxide dust or fumes can cause serious illness or death. Chronic effects due to exposure over long periods of time can also occur. Therefore, it is essential to protect workers performing operations that can generate dust or fumes.

Dust can be generated during rotor and cavity lapping operations. Fumes can be generated during the electro-discharge machining (EDM) of the rotors from the extruded beryllium rod. To protect operators from the potential dangers involved with these operations, special enclosures or work areas were provided. Standards established by the Massachusetts Department of Labor and Industries, Division of Occupational Hygiene were used to design the work areas (see appendix F for complete details). A consulting engineer with experience in these areas was also employed to consult on PPD's design of the work areas and to perform the analyses on air samples taken in the various areas.

For EDM operations on the rotor, a special Plexiglas shield was designed and built to enclose the entire dielectric fluid tank. Any fumes or dust particles generated during EDM are carried off by the vacuum ports and hose. This possibly contaminated air is piped into a special plant beryllium vacuum system. The air is then filtered to remove particles and vented to atmosphere. It should be noted at this point that all operations involving beryllium or beryllia are performed "wet", that is in the presence of lapping slurries or dielectric fluid. This greatly reduces the possibility of air-borne particles. Figure 14 is a photo of the Electro-Discharge Machine.

Lapping operations on the rotor and cavities are carried out in specially modified booths shown in figure 15. The faces of the booths are covered with Plexiglas into which circular access ports have been cut. A 6-inch diameter main vacuum pipe extends the length of the rotor booth and

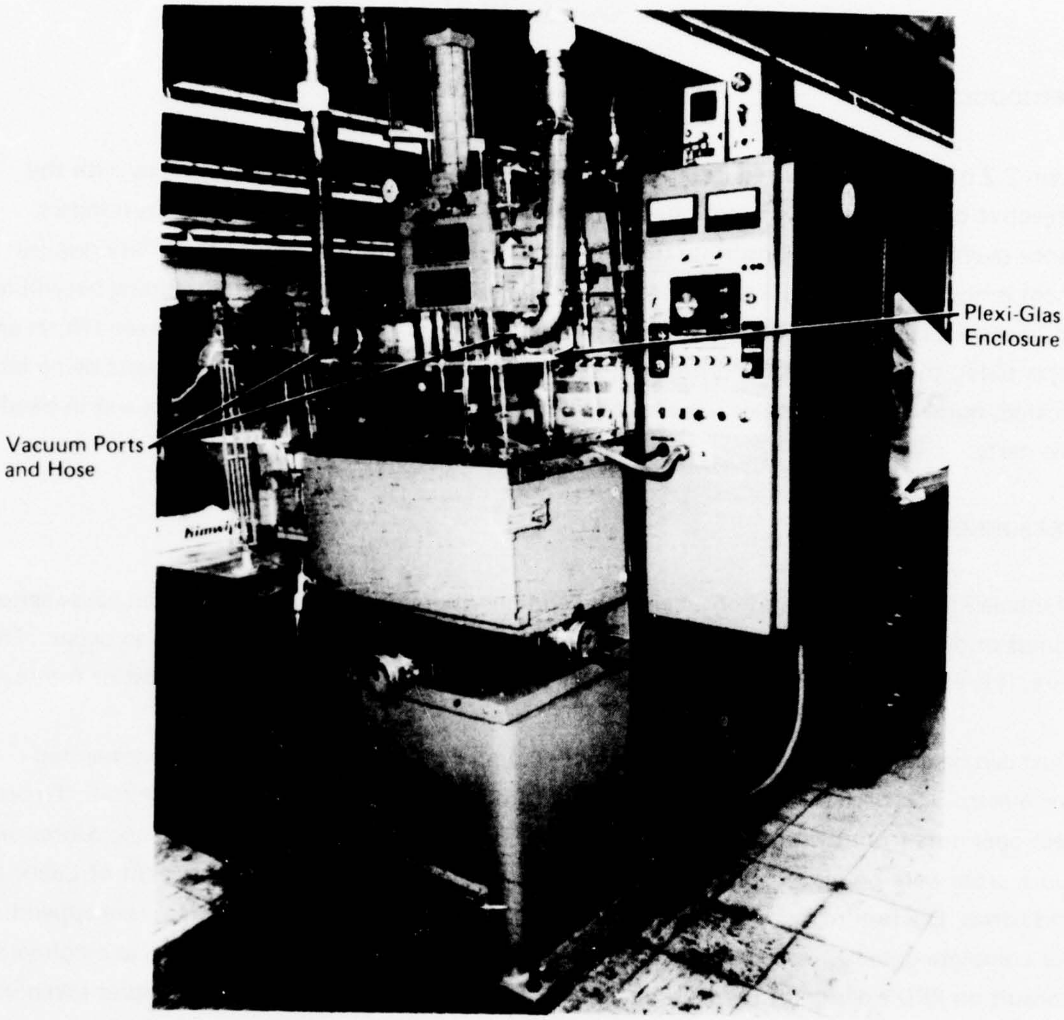


Figure 14. Electro Discharge Machine

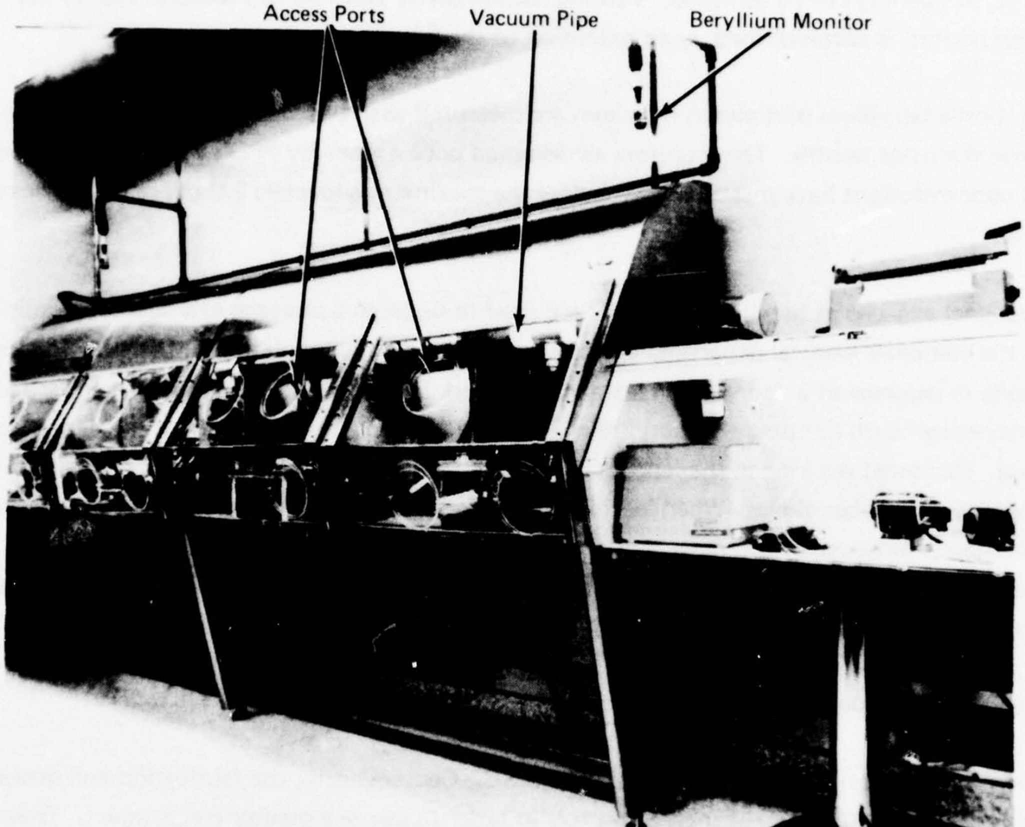


Figure 15. Rotor and Cavity Lapping Booths

is connected to the plant's central beryllium vacuum system. The pipe is fitted with four vacuum ports along its length which are opened according to which booth is in use. Access to the lapping machines is achieved by use of the access ports through which the operator extends his arms as required. With this system, opening only the access ports required, 200 cu. ft./min./sq. ft. of opening can be achieved. Venting for the cavity work booth, located next to the rotor booths, is accomplished by an extension of the 6-inch vacuum main.

Air-borne beryllium particles in the room are measured with two beryllium monitors mounted above the rotor booths. The monitors are sampled once a week by PPD's medical department. All concentrations have measured well below the maximum allowable 2.0 micrograms per cubic meter.

Personnel engaged in beryllium work are required to undergo a physical examination administered by the company medical department once a year. Successful completion of the examination results in issuance of a "beryllium clearance" to work in areas designated as beryllium areas. Personnel who do not possess a beryllium clearance are not permitted to enter the designated areas. Personnel working in the lapping room wear booties and smocks and when engaged in lapping wear rubber gloves. When leaving the lapping room, personnel are required to wash their hands thoroughly to remove any dust particles that may have adhered to their hands. These precautions, adhered to in the MESG lapping area, as well as other beryllium areas in the plant, have resulted in an excellent safety record for all personnel involved.

IN-PROCESS PRECAUTIONS

The rotor and cavity set is the heart of the MESG. Consequently, the fabrication and measurement process require very stringent controls in order to insure a quality end product. These controls during the fabrication process involved quality of lapping compound to insure that no contaminants are present in compound during lapping operations. (Even minute particles of contamination will scratch the rotor or cavity.) Cleaning of parts is very critical before changing compounds. The rotors are fabricated from beryllium and can be damaged very easily from dents, scratches, digs, gouges and particle tearout. The rotors go through many lapping operations and are handled many times during fabrication, which makes the probability of damage very high. Therefore, PPD has made a maximum effort to incorporate safety features into all fabrication fixturing (e.g., special handling tweezers for removing rotors from the lapping instruments and special tweezers for cavity handling). Every lapping instrument has been covered with foam rubber to insure that no damage results to a rotor if it falls or is dropped from laps while being handled near instruments. Each operator wears rubber gloves while fabricating and cleaning rotors. All of the handling tools and instruments have been designed with safety of the part in mind, and are made from Teflon, Nylon, or rubber. All tools are cleaned prior to

placing any part on or in them. All laps, holding fixtures, handling tools, and glassware have been identified so that no part can get placed in an area that would result in damage to the part. Scratches in the rotor can result from improper lapping pressure, handling, and contaminated compounds. Dents and dings usually occur during the measurement process, typically as a result of excessive stylus pressure, and dropping or mishandling the rotor or cavity. PPD has investigated potential hazards during measurement and taken steps to eliminate them. Each rotor measurement instrument and the table top work area have been covered with foam rubber. The cavity measurement area is also covered with foam rubber and parts are handled with gloves and special tweezers. Rotors are protected from damage on the proficorder by drawing a slight vacuum on the rotor holding fixture which is also covered with foam rubber. The cavity is protected by clamping the part in the fixture. Figure 16 is a photograph of the rotor measurement area.

All these efforts have resulted in minimum loss of in-process parts from accidental causes.

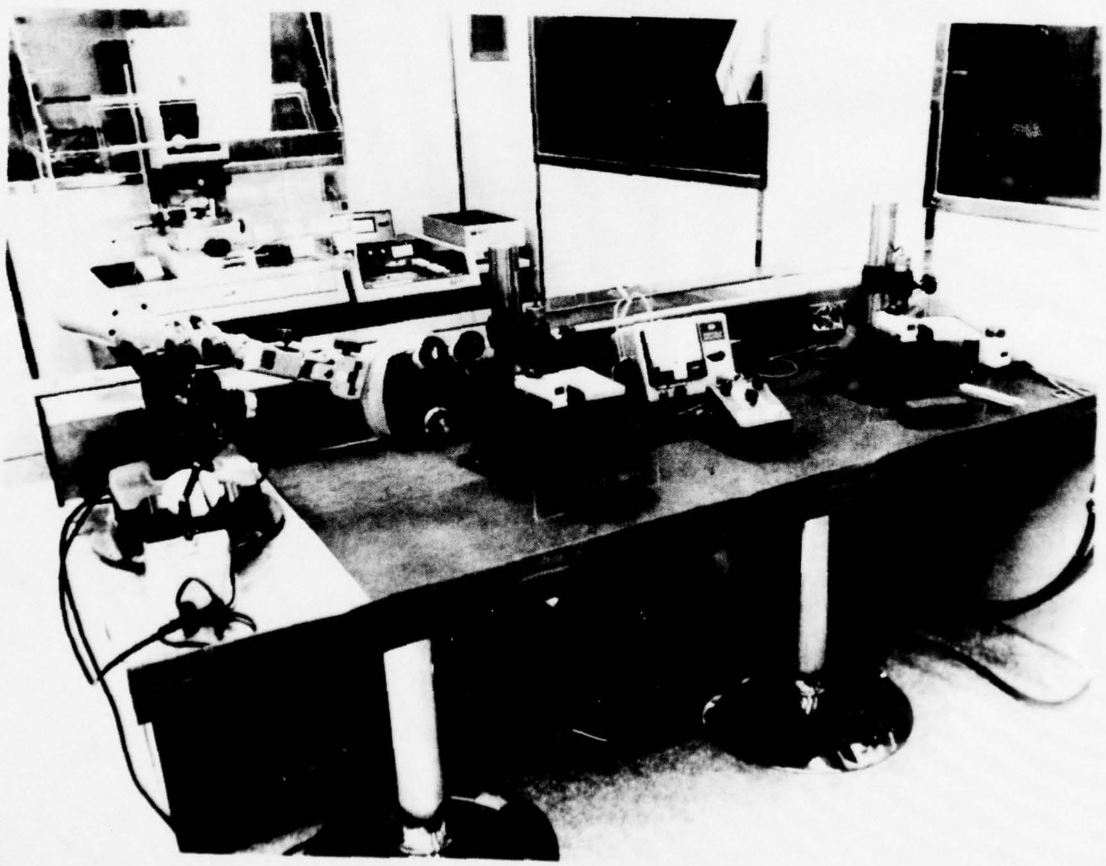


Figure 16. Rotor Measurement Area

Appendix A

Listing of
AGRI Tools, Drawings, and Specs

TOOLS

Number	Title
10000-207	Rotor Lapping Machine
10001-207	Base, Rotor Lapping Machine
10002-207	Cartridge Holder, Rotor Lapping Machine
10003-207	Insulator, Rotor Lapping Machine
10004-207	Shaft, Rotor Lapping Machine
10005-207	Cap, Rotor Lapping Machine
10006-207	Spindle, Rotor Lapping Machine
10007-207	Body, Rotor Lapping Machine
10008-207	Bushing, Rotor Lapping Machine
10009-207	Clamp, Rotor Lapping Machine
10010-207	Adapter, Rotor Lapping Machine
10011-207	Pin, Rotor Lapping Machine
10012-207	Lap, Rotor Lapping Machine
10013-207	Lock Pin, Cartridge, Rotor Lapping Machine
10014-207	Washer, Rotor Lapping Machine
10015-207	Plate, Rotor Lapping Machine
10016-207	Wheel, Rotor Lapping Machine
10017-207	Trunnion, Rotor Lapping Machine
10018-207	Shaft, Crank, Rotor Lapping Machine
10019-207	Spacer, Rotor Lapping Machine
10020-207	Block, Rotor Lapping Machine
10021-207	Slide, Rotor Lapping Machine
10022-207	Way, Rotor Lapping Machine

Number	Title
10023-207	Clamp, Rotor Lapping Machine
10024-207	Handle, Rotor Lapping Machine
10025-207	Bushing, Rotor Lapping Machine
10026-207	Block, Rotor Lapping Machine
10027-207	Pully Motor, Rotor Lapping Machine
10028-207	Cam, Slide, Rotor Lapping Machine
10029-207	Shim, Motor, Rotor Lapping Machine
10030-207	Bracket, Rotor Lapping Machine
10031-207	Shield, Rotor Lapping Machine
10032-207	Comparator, Cavity Spherometer
10033-207	Head Spherical Dia. Comp.
10034-207	Tip, Spherical Dia. Comp.
10035-207	Tip and Weight, Spherical Dia. Comp.
10036-207	Support Ring, Spherical Dia. Comp. ESG
10037-207	Nut , Collet, Spherical Dia. Comp. ESG
10038-207	Cartridge Holder, Spherical Dia. Comp.
10039-207	Comparator, Cavity Equator ESG
10040-207	Head, Comp. Cavity Equator
10041-207	Tip, Comp. Cavity Equator
10042-207	Comparator, Cavity Equator Chamfer
10043-207	Head, Cavity Equator Chamfer
10044-207	Pin, Cavity Equator Chamfer Comp.
10045-207	Gage, Cavity Equator Chamfer
10046-207	Ring Set Master, Cavity Comp.
10047-207	Disc. Set Master, Cavity Comp.
10048-207	Slot Lapping Fixture

Number	Title
10049-207	Holder, Slot Lapping Fixture
10050-207	Base, Slot Lapping Fixture
10051-207	Retainer, Slot Lapping Fixture
10052-207	Rotator, Slot Lapping Fixture
10053-207	Alignment Gage, Slot Lapping Fixture
10054-207	Cutter, Slot Lapping Fixture
10055-207	Slide, Slot Lapping Fixture
10056-207	Cavity Lapping Machine
10057-207	Holder, Cavity Lapping Machine
10058-207	Lap, Cavity Machine
10059-207	Spindle, Cavity Lapping Machine
10060-207	Spindle, Cavity Lapping Machine
10061-207	Collar Driver, Cavity Lapping Machine
10062-207	Adapter, Cavity Lapping Machine
10063-207	Standoff, Cavity Lapping Machine
10064-207	Plate, Side, Cavity Lapping Machine
10065-207	Gusset, Cavity Lapping Machine
10066-207	Arm, Connecting Cavity Lapping Machine
10067-207	Bracket Assembly, Cavity Lapping Machine
10068-207	Indicator, Cavity Lapping Machine
10069-207	Crank, Cavity Lapping Machine
10070-207	Arm, Cavity Lapping Machine
10071-207	Block, Pillow, Cavity Lapping Machine
10072-207	Shaft, Cavity Lapping Machine
10073-207	Bracket, Cavity Lapping Machine
10074-207	Base, Cavity Lapping Machine
10075-207	Indexing Fixture Pot Chuck

Number	Title
10076-207	Electrode Elox
10077-207	Cavity Holder
10078-207	Mask, Sputter
10079-207	Cavity Holder Talyrond
10080-207	Cavity Grind Fixture
10081-207	Shield Rotor Lapping Machine
10082-207	Cover Rotor Lapping Machine
10083-207	Probe, Temp. - Rotor Lapping Machine
10085-207	Lap Charging Fix
10089-207	Rotor Measuring Fixture - Talyrond
10090-207	Bake Fixture, Rotor
10205-217-1	Ball Holder (Bake out)
10206-217	Cavity Holder
66532-207	Rotor Cleaning Fixture
66533-207	Cavity Cleaning Fixture

GYRO DRAWINGS

Number	Title
12504-302	Rotor
12698-302	Cavity, Rotor
12699-302	Cavity, Rotor (Plated)
12700-302	Cavity Assembly, Rotor
12795-302	Billet Extrusion Rotor
12796-302	Extrusion Rotor

SPECIFICATIONS

Number	Title
AA0103-004	Electrical discharge machining
AA0104-001	Marking of electrical & mechanical items
AA0109-008	Electrodeposition of a copper strike upon base metal
AA0109-009	Deposition of electroless nickel phosphorous plate
AA0109-023	Preparation of basis metal for final plating
AA0109-050	Sputter deposition of chromium & gold on beryllium oxide
AA0109-051	Electroless deposition of nickel-phosphorous plated gold
AA0110-008	Cleaning of beryllium
AA0110-028	Solvent vapor degreasing
AA0110-032	Abrasive cleaning
AA0110-035	Solvent and detergent cleaning inertial instrument components
AA0111-003	Thermal treatment of beryllium
AA0115-003	Determination of magnetic susceptibility for plating used in precision instruments
AA0117-004	Handling of flammable and dangerous liquids and chemicals
AA0117-005	Safety & environmental health requirements for the machining and handling of beryllium alloys & compounds
AA0115-006	Ceramic, beryllium oxide, dense
AB0170-067	Beryllium extruded (for precision instrument applications)
AB0210-007	Trichlorotrifluorethane (type TF) solvent, high purity grade.
AB0210-008	Solvent, petroleum
AL70030	Hot lapping procedure for rotor

Number	Title
AL70032	Cavity lapping procedure
ST0115AA0010	Tolerances, surface finish and standard configurations
ST0115AA0089	Radiographic inspection
ST0115AA0103	Requirements for clean rooms, clean work stations, and controlled areas
ST0115AA0114	Penetrant inspection, general requirements for
ST0140AB0012	Grease ball and roller bearing, sodium base
ST0170AB0002	Beryllium billet, bar and shapes

Appendix B

PPD Material Specs

DASH NO.	APPLICATION		REVISION			
	NEXT ASSY	USED ON	LTR	DESCRIPTION	DATE	APVD
		ESG	A	Released per DER 2698-A	4 FEB 75	DBA

NOTE:

Only the item described on this drawing when procured from the vendor(s) listed hereon is approved by Northrop Corporation Electronics Division, Norwood, Massachusetts, for use in the applications specified hereon. A substitute item shall not be used without prior testing and approval by Northrop, Rockwell International or the U. S. Air Force.

SOURCE CONTROL DRAWING

REV																														
SH	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56
REV STATUS	REV		A	A	A	A	A	A	A	A																				
OF SHEETS	SH		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26		

CONTRACT NO. F33615-74C-1105 A4HM-557166-F-E		
DWN Harry Salmi	31 Jan 75	**NORTHROP** Northrop Corporation Electronics Division Norwood, Massachusetts
CHK J. Jaquinuzzi	31 Jan 75	
ENGR F. O. Kallock	31 Jan 75	
APVD A. R. Tracey	31 Jan 75	STANDARD GRADE BERYLLIUM, MATERIAL SPECIFICATION FOR
APVD R. Westhause	31 Jan 75	
APVD DBF	4 Feb 75	
NORTHROP APPVL W. L. Marlett	31 Jan 75	SIZE A — CODE IDENT NO. 88932 — 68848
CUSTOMER APPVL		SCALE NONE — SH 1 of 8

1. SCOPE

1.1 This specification defines the requirements for standard grade beryllium block intended for gyro applications.

2. APPLICABLE DOCUMENTS

2.1 The following documents of the issue in effect on the date of invitation for bids, form a part of this specification to the extent specified herein.

SPECIFICATIONS

Military	MIL-I-6866	Inspection, Penetrant Method of

STANDARDS

Society	American Society for Testing and Materials Standard Methods of Test or Approved Equivalent	
Military	MIL-STD-453	Inspection, Radiographic
Federal	FED-STD-151	Metals, Test Methods

2.2 When a requirement of an applicable document is in conflict with one specified herein, the requirement specified herein shall apply. When a requirement specified on a drawing or purchase order is in conflict with one specified herein, the requirement specified on the drawing or purchase order shall apply.

3. REQUIREMENTS

3.1 Material. The materials used shall be of such quality and purity that the finished product shall have the properties and characteristics prescribed herein.

3.2 Material Composition. The material supplied shall be hot pressed from -325 mesh virgin powder.

3.3 Condition. The material shall be supplied hot pressed to meet the mechanical property requirements of this specification. Standard surface finish shall be 125 microinches AA, maximum.

3.4 Chemical Composition. The material shall conform to the following chemical composition:

STANDARD GRADE BERYLLIUM, MATERIAL SPECIFICATION FOR	DWG SIZE A	CODE IDENT NO. 88932	68848
	SCALE NONE	REV A	SHEET 2

Constituent	Weight Percent Min.	Max.
Beryllium	98.0	
Beryllium Oxide	0.7	2.0
Aluminum		0.14
Carbon		0.15
Iron		0.18
Magnesium		0.08
Silicon		0.10
Other metallic impurities		0.04

each as determined by normal spectrographic methods.

3.5 Mechanical Properties. Material supplied per this specification shall have the following mechanical properties in the transverse direction at room temperature. See paragraph 6.1.

Ultimate tensile strength, psi	40,000 min.
Yield strength (0.2% offset), psi	30,000 min.
Elongation (% in 1 inch)	1.0 min.

3.6 Density. The density shall not be less than 99 percent of theoretical density nor more than 101 percent of theoretical density based on the beryllium and beryllium oxide content.

3.7 Soundness. Radiographic and/or visual indications (voids and/or inclusions) shall conform to the requirements as established below.

3.7.1 Maximum Dimensions of Any Indication. Any dimension of an indication measured in the plane of the radiograph shall not exceed 0.030 inch.

3.7.2 Maximum Average Dimensions of Any Indication. The average dimensions of an indication shall not exceed 0.015 inch. The average dimension of an indication shall be the arithmetic average of the maximum and minimum dimensions measured in the plane of the radiograph.

3.7.3 Total Combined Volume of All Indications. The total combined volume per cubic inch of all indications with an average dimension larger than 0.001 inch shall not exceed the volume of a sphere of 0.020 inch diameter.

3.7.4 Banding. Low density radiographic traces caused by banding or striation shall not vary in film density by more than 5% as compared to surrounding areas of comparable section thickness. See paragraph 6.1

3.8 **Grain Size.** The average grain size shall not exceed 30 microns.

3.9 **Tolerances.** Material furnished under this specification shall conform to the dimensions and dimensional tolerances established by the purchase order and applicable drawings. If tolerances are not specified by the purchase order the following standard tolerances shall apply.

Diameter, Width or Thickness, Inches	Tol.Inch
Up to 3, inclusive	-0 + 1/64
Over 3 to 20, inclusive	-0 + 1/16
Over 20	-0 + 1/4

Length, Inches	
Up to 20, inclusive	-0 + 1/8
Over 20	-0 + 1/4

4. QUALITY ASSURANCE

4.1 **Quality Control.** The supplier is responsible for the maintenance of adequate quality control necessary to ensure that the material supplied meets the requirements of this specification. The supplier shall afford the purchaser all reasonable facilities, including access to relevant inspection records when required, to satisfy him that material is being furnished in accordance with this specification.

4.2 **Quality Conformance Tests.** Tests for acceptance of individual lots shall consist of tests for:

a. Chemical composition.
b. Mechanical properties.
c. Density.
d. Soundness.
e. Grain Size.

4.2.1 **Chemical Composition.** Each lot shall be tested for conformance to the chemical compostion requirements as specified in 3.4.

4.2.2 **Mechanical Properties.** Each lot shall be tested for conformance to the mechanical properties of 3.5.

4.2.3 Density. Each lot shall be tested for conformance to the requirements of 3.6.

4.2.4 Soundness. Each lot shall be tested for conformance to the requirements of 3.7 on a test blank of material, 1/2 inch thick.

4.2.5 Grain Size. Each lot shall be tested for conformance to the requirement in 3.8.

4.3 Test Methods

4.3.1 Chemical Composition. Samples shall be tested to ASTM Standard Methods of Test or approved equivalent.

4.3.2 Mechanical Properties. Samples shall be tested in accordance with ASTM E8 and Federal Test Method No. 151.

4.3.3 Density. Samples shall be tested in accordance with ASTM B-311.

4.3.4 Soundness. Radiographic inspection of samples to a penetrameter sensitivity of 2% shall be performed in accordance with MIL-STD-453. Penetrant inspection of samples shall be performed in accordance with MIL-I-6866.

4.3.5 Grain Size. Samples shall be tested in accordance with ASTM E112, Section 7b.

4.4 Test Report. Unless otherwise specified, the manufacturer shall furnish a certified test report in duplicate to the Northrop Electronics Buyer referred to on the Purchase Order, giving the results of tests required to determine conformance with the chemical, mechanical and physical property requirements specified herein of the hot pressed powder lot or lots from which the parts were made. The test report shall be signed by the Director of the Laboratory in which the tests are conducted, or by any person designated by him.

5. PREPARATION FOR DELIVERY

5.1 Packing. All material shall be packed in accordance with the best practice so as to insure against the occurrence of toxicological hazards during normal shipment.

5.2 **Marking.** All shipments shall be marked with a description of the contents, the quantity contained therein, the name of the manufacturer, and the Northrop Electronics specification and Purchase Order numbers.

5.2.1 A "hazardous material" warning label shall be posted conspicuously on all packages or lots of this material, such as:

WARNING
Beryllium Product
Hazardous Dusts Produced
when Machined, Filed or Ground

6. **NOTES**

6.1 **Definitions**

6.1.1 Longitudinal direction is parallel to the direction of pressing and the transverse direction is in a plane 90° to the longitudinal direction.

6.1.2 **Samples.** The term samples shall denote material produced integrally with a block and for purposes of quality assurance testing pursuant to the requirements of section 3. Samples shall be located in a block such that they bracket the block as shown in Figures 1 and 2, or such that they are otherwise representative of the block.

6.1.3 **Lot.** The term lot shall denote material submitted for inspection at one time which meets all of the following conditions:

(a) Shall be of a single size and configuration.
(b) Shall be from a single block.

6.1.4 **Block.** The term block shall denote a scalped hot-pressing, or a portion thereof, from which samples are taken and from which blanks are taken.

6.1.5 **Blanks.** The term blanks shall denote pieces (of a block) whose dimensions are such that a discrete number of parts are intended to be produced therefrom.

6.1.6 **Banding.** The term banding shall denote relatively large areas of a radiograph which vary in radiographic density as compared to the surrounding area. Such bands are sometimes referred to as variable density areas or striations. The term banding does not encompass discretely resolvable radiographic indications of inclusions or voids.

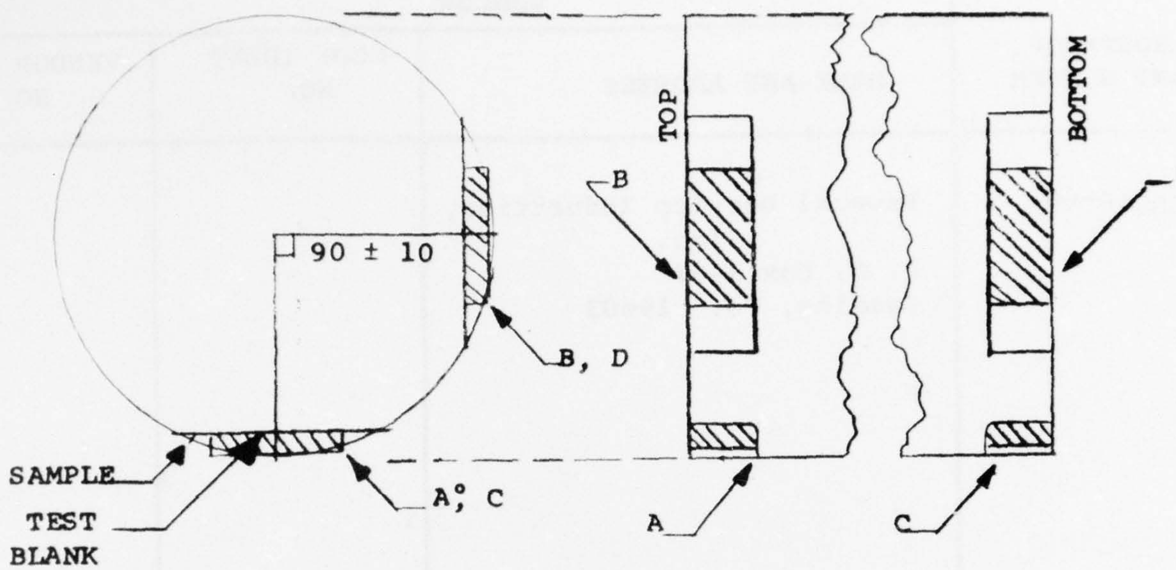


FIGURE 1 -- CYLINDRICAL BLOCKS

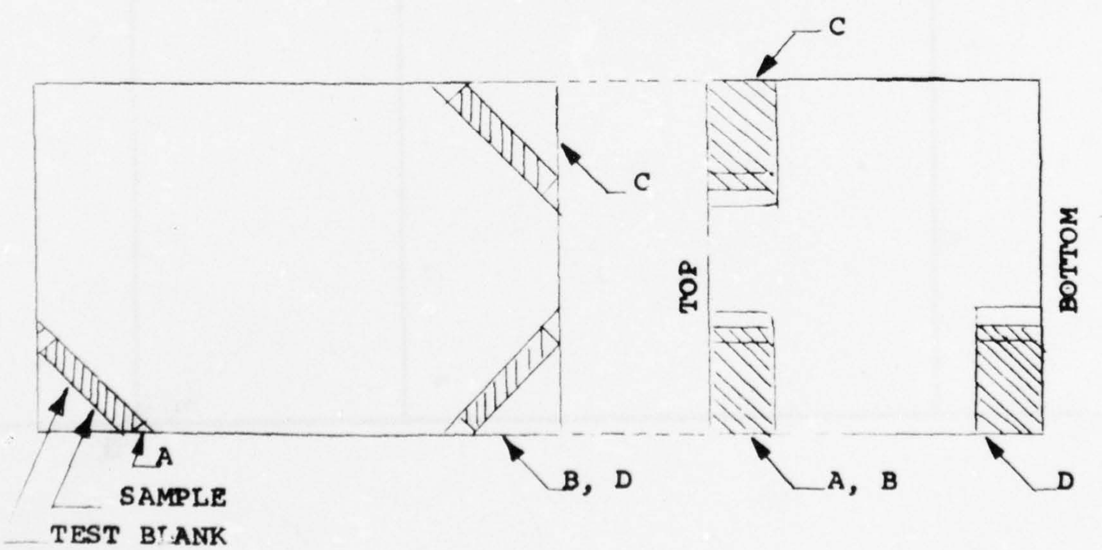


FIGURE 2 -- RECTANGULAR BLOCKS

STANDARD GRADE BERYLLIUM, MATERIAL SPECIFICATION FOR	DWG SIZE A	CODE IDENT NO. 88932	68848
	SCALE NONE	REV A	SHEET 7

APPROVED

TABLE I SOURCES OF SUPPLY

NORTHROP PART NUMBER	VENDOR NAME AND ADDRESS	CODE IDENT NO.	VENDOR PART NO.
68848-001	Kawecki Berylco Industries, Inc. P. O. Box 1462 Reading, Pa. 19603		

STANDARD GRADE BERYLLIUM, MATERIAL SPECIFICATION FOR	DWG SIZE A	CODE IDENT NO. 88932	68848
	SCALE None		SHEET 8

DASH NO.	APPLICATION		REVISION			
	NEXT ASSY	USED ON	LTR	DESCRIPTION	DATE	APVD
		ESG	A	Released per DER 2698B	10 FEB 75	DBA

NOTE:

Only the item described on this drawing when procured from the vendor(s) listed hereon is approved by Northrop Corporation Electronics Division, Norwood, Massachusetts, for use in the applications specified hereon. A substitute item shall not be used without prior testing and approval by Northrop, Rockwell International or the U.S. Air Force.

SOURCE CONTROL DRAWING

REV																														
SH	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56

REV STATUS	REV	A	A	A	A	A	A	A	A																					
OF SHEETS	SH	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26

CONTRACT NO. F33615-74C-1105
A4HM-557166-F-E

DWN	[signature]	7 FEB 75
CHK	J. Yapuzziello	10 FEB 75
ENGR	F. V. Hallock	7 FEB 75
APVD	[signature]	10 FEB 75
APVD	R. Wathen	10 Feb 75
APVD	DB [signature]	10 FEB 75
NORTHROP APPVL	[signature]	10 Feb 75
CUSTOMER APPVL		

NORTHROP

Northrop Corporation
Electronics Division
Norwood, Massachusetts

MATERIAL SPECIFICATION FOR DENSE BERYLLIA

SIZE	CODE IDENT NO.	
A	88932	68849
SCALE		SH 1 of 8

1. SCOPE

1.1 This specification records the procurement requirements for one type of beryllia intended for inertial gyro applications. It is a dense grade with high thermal conductivity, good resistance to thermal shock and chemical inertness.

2. APPLICABLE DOCUMENTS

2.1 The following documents of the issue in effect on the date of invitation for bids, form a part of this specification to the extent specified herein.

SPECIFICATIONS

Military	MIL-I-6866	Inspection, Penetrant Method of
	MIL-I-10	Insulating Materials, Electrical, Ceramic

STANDARDS

Society	ASTM Standard Methods of Test

2.2 **When a requirement of the applicable document is in conflict with one specified herein, the requirement specified herein shall apply. When a requirement on the drawing or Purchase Order is in conflict with one specified herein, the requirement specified on the drawing or Purchase Order shall apply.**

3. REQUIREMENTS

3.1 Material. **The material used shall be natural mineral so compounded that, when pressed, extruded or otherwise processed, then fused or sintered by heat, it provides an insulating compound meeting the requirements of this specification.**

3.2 Chemical Composition. The material shall consist of 99.5% beryllia, nominal.

3.3 Uniformity

3.3.1 Acceptable uniformity for this grade of material depends upon all of the following.

MATERIAL SPECIFICATION FOR DENSE BERYLLIA	DWG SIZE A	CODE IDENT NO. 88932	68849
	SCALE NONE	REV A	SHEET 2

3.3.2 <u>Cracks</u>. The material shall not exhibit any crack to normal vision when tested in accordance with 4.2 and 4.2.1.

3.3.3 <u>Surface Defects</u>. Surface defects (defects other than cracks or discolorations) shall be defined as discontinuities or depressions in the surface of the material which are visible to normal vision when tested in accordance with 4.2 and 4.2.1. (Normal vision will generally be considered capable of observing surface defects 0.010 inch in diameter and larger). A visible surface defect which is not a discontinuity shall not be cause for rejection.

3.3.4 <u>Discolorations</u>. The material shall not exhibit to normal vision any discoloration due to contamination where the discoloration appears as discolored areas surrounding cores or nodules of foreign materials (i.e., iron spots, grinding media and similar contamination). Discolorations not containing cores or nodules of foreign material, such as pink chrome stains, shall not constitute basis for rejection of the material.

3.4 <u>Dimensions and Tolerances</u>. Unless otherwise specified on the drawing or purchase order, tolerances shall be ±0.005 inch or ±1% of the specified dimension, whichever is greater.

3.5 <u>Properties</u>

3.5.1 When tested in accordance with the specified methods, this material shall conform to MIL-I-10, Class L423, with the exceptions or additions specified in Table I.

TABLE I

EXCEPTIONS OR ADDITIONS TO MIL-I-10, CLASS L423

Property	Value	Test Method Paragraph
*Apparent Specific Gravity, gm/cc, minimum	2.85	4.2
Cracks and Surface Defects	As specified on drawing	4.2 & 4.2.1
Thermal Conductivity at 106°C, cal/sec(cm^2)(degree C/cm) minimum	0.42	4.2

*Specific gravity shall be taken for each lot of substrates. Other test methods such as "sink float" are satisfactory for acceptance requirements, provided the results correlate with those using ASTM C-20, the governing specification.

MATERIAL SPECIFICATION FOR DENSE BERYLLIA	DWG SIZE A	CODE IDENT NO. 88932	68849
	SCALE NONE	REV A	SHEET 3

4. QUALITY ASSURANCE

4.1 Quality Control. The supplier is responsible for the maintenance of adequate quality control necessary to ensure that the material supplied meets the requirements of this specification. The supplier shall afford the purchaser all reasonable facilities, including access to relevant inspection records when required, to satisfy him that material is being furnished in accordance with this specification. In addition, the manufacturer shall furnish the purchaser one properly identified sample specimen with each lot of material shipped that is representative of the manufacture and heat treatment of the lot.

4.1.1 Lot. A lot shall be defined as material pressed from a blend of one batch of powder. If a shipment is made from more than one lot, the purchaser may choose to consider this shipment as a single lot or may separate the shipment into lots for acceptance purposes.

4.2 Test Methods. Tests for acceptance of individual lots shall be conducted in accordance with those specified in Table II.

TABLE II
TEST METHODS

Property	Requirement Paragraph	Test Method
Cracks & Surface Defects	3.3.2,3.3.3,3.3.4	MIL-I-6866
Thermal Conductivity	3.5.1	ASTM C-408
Apparent Specific Gravity	3.5.1	ASTM C-20
Flexural Strength	3.5.1	ASTM D-116

4.2.1 Cracks and Surface Defects

4.2.1.1 Rack parts to reduce surface contact prior to immersion in dye penetrant. The parts shall remain submerged for 4 to 6 minutes.

4.2.1.2 After removing from dye tank, allow parts to drain for 5 to 10 minutes prior to rinsing (spray or dip) in tap water to remove unwanted concentrations of dye. Dry in circulating air dryer at 150 to 170°F until dry.

4.2.1.3 Inspect for cracks and surface defects by transmitted light (275 foot candles, minimum, at workpiece) using normal 20/20 vision. Magnification may be used for "screening" prior to inspection to reduce operator fatigue. Room lighting should not exceed 30 foot candles at the work area. In addition, the area immediately around the substrate being viewed should be masked to shield direct light from the inspector's eyes.

4.2.1.4 Incident light (angle of incidence less than 5° to surface of substrate) shall be used to detect surface defects such as pits, voids and scores.

4.2.1.5 Questionable cracks or surface defects shall be verified by the use of magnification up to 30X to determine and/or verify the extent and nature of the defect.

4.3 Test Reports. When specifically required on the contract or Purchase Order, the manufacturer shall furnish a certified test report in duplicate to the Northrop Electronics Buyer referred to on the Purchase Order, giving the results of tests required to determine conformance with the Chemical, Mechanical, Density and Thermal conductivity requirements specified herein. The test report shall be signed by the Director of the Laboratory in which the tests are conducted, or by any person designated by him.

5. PREPARATION FOR DELIVERY

5.1 Packaging. The material shall be packaged in accordance with the manufacturer's commercial practice to assure safe delivery by common carrier and prevent contamination by dirt, moisture or other foreign material during normal handling.

5.2 Marking

5.2.1 All shipments shall be marked with a description of the contents, the quantity contained therein, the name of the manufacturer and the Northrop Electronics Specification and Purchase Order numbers. In addition, all parts contained in each shipment shall be marked with the manufacturer's lot or batch number that will identify the processing details to which the parts have been subjected.

5.2.2 The material shall be marked or tagged with a suitable warning notice to the effect that the material may be toxic when ground or filed.

6. NOTES

6.1 Definitions. The following definitions for terms used in this specification shall apply:

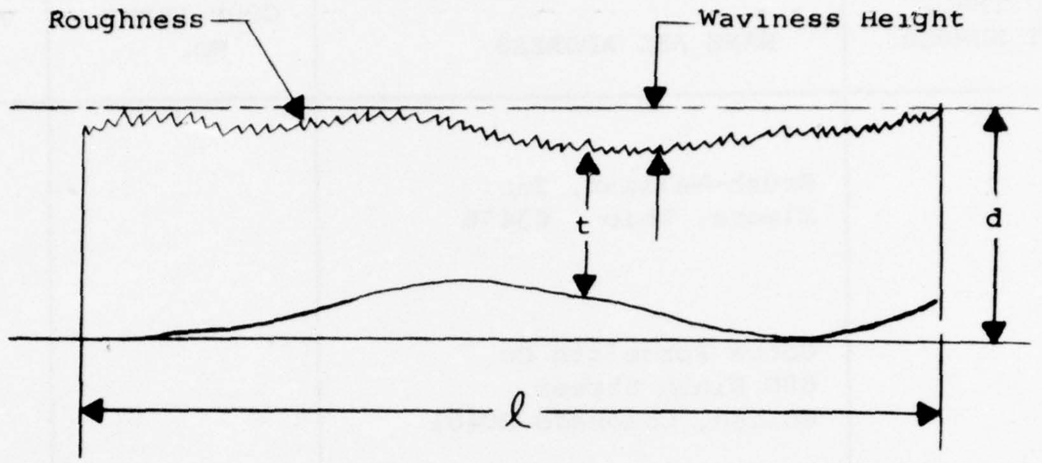
6.1.1 Roughness. The smallest irregularities on the surface of the substrate, the heights of which are of the order of ten micro-inches. Roughness Width refers to the distance between repetitive patterns of these fine spaced irregularities. Thus, the roughness width cutoff value established the distance on the surface (in inches) which is used in computing the arithmetic average deviation (AA) of the roughness heights from the mean value.

6.1.2 Waviness. Irregularities in the surfaces which are more widely spaced than the roughness irregularities. The waviness height is usually specified as the peak-to-valley distance in inches. Waviness width is the distance along the surface in inches which is included in computing the maximum peak-to-valley distance.

6.1.3 Camber. The gross deviation of the substrate from a plane surface. The total of the curvature of the substrate as a whole plus out-of-parallelism. A convenient method of specifying the camber is to determine the ratio of the difference between thickness of the part measured as a whole and the thickness at one point to the length of the part (See Figure 1).

6.1.4 Projections. Any localized irregularities in the substrate surface which have a convex curvature. Projections are not periodic as is the roughness and have heights at least 10 times the arithmetic average surface roughness.

6.1.5 Scratch. A concave surface irregularity which is at least 10 times greater in extent in one direction than in all other directions.



$$\text{Camber} = \frac{(d - t)}{\ell}$$

where t = Average part or lot thickness as measured with ball or poin micrometer.

d = Part thickness measured with flange micrometer or parallel plates encompassing the entire surface or TIR value obtained with a dial indicator system.

ℓ = Part length.

NOTE: All dimensions in inches.

Figure 1 - Cross Section of Ceramic Substrate

MATERIAL SPECIFICATION FOR DENSE BERYLLIA	DWG SIZE A	CODE IDENT NO. 88932	68849
	SCALE NONE	REV A	SHEET 7

APPROVED

TABLE I SOURCES OF SUPPLY

NORTHROP PART NUMBER	VENDOR NAME AND ADDRESS	VENDOR CODE IDENT NO.	VENDOR PART NO.
	Brush-Wellman, Inc. Elmore, Ohio 43416		
	Coors Porcelain Co 600 Ninth Street Golden, Colorado 80401		

MATERIAL SPECIFICATION FOR DENSE BERYLLIA	DWG SIZE A	CODE IDENT NO. 88932	68849
	SCALE NONE	REV A	SHEET 8

Appendix C

KBI Letter, Process Specs and Extrusion Billet Assembly Drawing

KAWECKI BERYLCO INDUSTRIES, INC.

KBI

P. O. Box 1462, Reading, Pa. 19603
Telephone: 215 / 929-0781

February 26, 1976

Mr. R. O. Westhaver
Northrop Electronics Division
100 Morse Street
Norwood, Mass. 02062

Dear Bob:

The following is in confirmation of my verbal communication of February 24, 1976 concerning questions outstanding from our meeting of December 23, 1975 to discuss the KBI process specification package supplied to Northrop Electronics for co-extruded beryllium rod containing tantalum wires:

1. Can design

   The plug is chamfered to lead the extrusion billet into the guide cone and die. The chamfer was not continued to the outer can wall since it was felt that in the initial stages of upsetting the billet the chamfer would be lost anyway.

   The can wall is 0.5 inches thick so that the extrusion billet can be accommodated in an existing extrusion press liner.

   A spacer ring is included only at the back of the extrusion billet assembly to avoid non-uniform pressure on the billet from weld build-up around the evacuation tube.

2. Reference SOP 614-310-05.001

   Diameter 0.62 + 0.030 - 0.000 inches in the title is correct according to attachment A exception 2 of the order.

   Page 2, Inspection of Billets, dimension O.D. 4.250 $\pm$ 0.030 inches does include measurement of the copper plating. The length dimension is incorrect as written in the SOP and should read 7.0 inches minimum to 7.5 inches maximum.

   Temperature as recorded in Figure 6 shows that temperature and time tolerances in section 3a, page 2 of the SOP were achieved.

3. Reference SOP 730-975-05.001
   On page 4 of this SOP after Paragraph 3.3 the title "Color Etch" should have been inserted. The extrusion was processed as called out in Paragraphs 3.4 through 3.12 of this SOP and subjected to etching for 3 minutes only. This etching procedure removes approximately 0.0005 inch maximum of metal per surface.

4. Tooling
   The code on the photographs of the tooling previously submitted to Northrop Electronics is explained as follows:

RMI C-815-1	Guide cone
RMI DI-114	Die
RMI 144-2	Runout guide

Die angle is 45 degrees

5. Extrusion Billet Temperature Measurement
   The temperature of the extrusion billet is measured in the furnace during pre-heating only. The temperature is not measured again after removal of the billet from the furnace.

   The foreign body detected in the tail of the extrusion could conceivably be the remainder of the stem attached to the outer can for evacuation purposes.

6. Future Developments
   It is suggested that prior to future extrusion campaigns KBI and Northrop Electronics consult together to determine potential means of improving the yield and properties of the co-extruded rod. It should be remembered that this may necessitate the purchase of new tooling and the use of additional trial runs. Trial runs could conceivably be made using a beryllium billet only.

I hope these explanations satisfactorily complete our current obligations to Northrop Electronics on this phase of the program. If I can be of any further assistance in this connection and for any future program, please let me know. I hope that I shall be seeing you again in the near future.

With very best regards,

R. C. Fullerton-Batten

R. C. Fullerton-Batten
Technical Manager, Beryllium Programs

RCFB/fkn

Form #BH-1

STANDARD OPERATING PROCEDURE
KBI - HAZLETON PLANT

Prepared by	Date 8-26-75	Prod. Dept. Appr.	Date	Number: 614-310-05.001	Re
Mfg. Engr. Appr.	Date 8/26/75	Facil. Engr. Appr.	Date 8/28-75	Date Effective: August 25, 1975	Page 1
Qual.Assur.Appr.	Date 8/27/75		Date 8/26/75	Plant Manager Appr.	Date

Title:
Extrusion of KBI Beryllium Billet Assemblies ZHC4117 Rev. B into 0.62 +.030 -.000 inch Diameter Rod

General Purpose:
Outline procedures and practices to be followed at RMI Ashtabula, Ohio Extrusion Plant to extrude Beryllium Canned Billets into rods for KBI

Equipment:
3850 Ton "Lowey" Horizontal Extrusion Press and Auxiliary Equipment

Sunbeam Fce. with auxiliary controls gas fired

Tooling:
GPO-Lubricant
Fishe 604-D Lubricant
Die Ring DR-95
Dummy Blocks DU-469-4
Guide Cones C-815-1

If at any time an operator cannot follow the instructions contained herein, he MUST, (1) notify his foreman or supervisor of the problem as well as, (2) make a note of the problem on his run record and/or routing sheet. He SHOULD NOT take corrective action or alter his required operational techniques without first having supervisory permission. The exception to this rule would be emergency action to prevent, (a) personal injury, (b) loss of material, or, (c) equipment damage.

Equipment Continued:
Industrial Heating Equipment - Tooling Fce. with Auxiliary Controls - gas fired

Graphite Cannisters

Sling type hanger with monorail

Tooling Continued:
Dies DIH-3R1, DI-114 with A-1687 filler piece
Bolster BO-53
Container 3856 (4.450 S.SF.S)
Liner Holder No. 26-2
Liner No. 74-2
Stem ST-55-1 & SH-10-1 & ST-38-2
Run Out Guide Re-144-2 = 1.660" x 1.250" x 84 Lg.
Assorted Hand tools & inspect. tools
Wheelco Controller
Easterline Angus recorder for PSI

This proprietary information is released for outplant use by: Plant Manager / Date

Official Copies:

See last page

Prod.Supr. | Qual.Assur. | Facil.Engr. | Oper. | | Originator | Document Fi

Inspection of Billets

Beryllium canned billets that have been welded and copper sprayed will be dimensionally inspected and weighed and data will be recorded on production control cards (See Figure 1).

(a) Dimensions - O.D. 4.250 $\pm^{.030}_{.030}$ -- Length 7.5" min. to 8.0" max.

Extrusion Preparation

(1) Upon receipt of production notification, production engineering shall issue orders Figures 2, 3, & 4 to have the press changed in time to start the production campaign. After changing the press liner and stem, maintenance supervisor shall check the two for concentric alignment. Maximum variation of ± .050" will be allowed between stem and liner.

(2) Production engineering will also issue Figure 2, 3, & 4 to cover all supplies and tooling necessary for the campaign. Tooling is inspected upon receipt from OSV and placed in tool crib. After the tooling is used it is inspected before being returned to tool crib with production engineering making final disposition if it does not conform to print.

(3) Billet Pre-heating

(a) Coat canned billet with GP-0 Lubricant, place it in graphite cannister. Place graphite lid on top of cannister and place in Sunbeam furnace controlled at $1600^{\circ}\ {}^{+.025}_{-.000}$ F on low fire temperature. Time in furnace at temperature must be a minimum of 2½ hours and a maximum of 4 hours.

(b) Minor tooling, dummy block pre-heat to 600°F. Tooling is placed in tooling furnace the night previous and heated at 600°F overnight.

(c) Container temperature set at 720°F on Wheelco controller.

Extrusion Conditions

(1) Tooling Lubrication - Fiske D
(2) Ram Speed 40 - 60 I.P.M.
(3) End of ingot having sealed off tube against press stem.
(4) Extrusion air cooled in run-out trough.

Procedure

At the start of the campaign remove die from tooling furnace, insert it into the die ring. Lubricate die with Fiske D previous to extrusion.

Remove cone from tooling furnace and place it into liner by use of the ram in front of die. Coat liner and cone with Fiske D Lubricant.

Rev.	By	Date	Description

Remove graphite container from Sunbeam furnace, remove lid and dump out of cannister. Using sling type hanger on monorail, transfer billet to the press and place on billet lift with sealed tube stem facing the press stem. Insert billet into liner. Dummy block is positioned by dummy block lift and inserted into liner. Move stem forward and extrude billet through 7 ft. guide tube into runout trough until one-half of 2" long plug is extruded. Move die forward, push rod backout of die and shear off stud rod with Maco Shear. Allow rod to cool down below red heat before transferring it to insulation material on floor.

Data taken during the extrusion will be recorded on Figure 1 with psi chart from Esterline Angus recorder Figure 5 showing pressing during the push. Speed of ram is automatically set and read from a dial gage on extrusion press control equipment. Time at temperature for billet will be recorded from a thermocouple in the billet Figure 6 and thermocouple in the furnace Figure 7.

Distribution:
HEFuhrmeister
DKSchoenly
WOFrauson
JAtherton
DHeiser

Rev.	by	Date	Description

R.M.I COMPANY

PRODUCTION CONTROL CARD

BILLET NO.	BILLET CLASS	BOX NO.	PURCHASE OR PROD. ORDER NO.	SHIPPED WT.
XT 1179	Kawecki Berylco Ind., Inc.		H-30182	

DATE RCVD.	WORK ORDER NO.	SOURCE BY LOT NO.	EXTRUSION NO.	RECEIVED AT	CHECK WEIGHT
	1561		U-1086		

MATERIAL TYPE	SHAPE	REMARKS		
Mild Steel-clad Beryllium	Rod	0.869" O.D.	18	Jn

HEAT TREATING DATA	DATE	FURNACE	FURNACE TEMP.	BATH POSITION	REMARKS

1ST CYCLE IN TIME	1ST CYCLE OUT TIME	2ND CYCLE IN TIME	2ND CYCLE OUT TIME	3RD CYCLE IN TIME	3RD CYCLE OUT TIME	TOTAL HEAT TIME

ELAPSED TIME / QUENCH TEMP. / QUENCH TIME: (blank)

REMARKS: 2½" Tail

OUTSIDE DIAMETER FRONT MAX	FRONT MIN	REAR MAX	REAR MIN	INSIDE DIAMETER FRONT MAX	FRONT MIN	REAR MAX	REAR MIN	WALL VARIANCE FRONT MAX	FRONT MIN	REAR MAX	REAR MIN	INSP. INITIALS
4.263	4.259	4.262	4.260									Jn

LENGTH: 7¼"

EXTRUSION DATA	
DATE	12-10-75
FURNACE	3B.
FURNACE TEMP.	1600
TIME IN	11:45
TIME OUT	14:18
TOTAL TIME	
DIE NO.	3R/-1+114-1
TRANS. TIME	48
REMARKS	RS: 60 IPM
BATH POSITION	1
DIE TEMP.	600 °F
P.S.I. START	1450
	PSI X .776 = TONS
ORIENTATION OF THIN WALL	
MANDREL NO.	
P.S.I. RUN	1230
	+550 TONS FOR BOOSTER
RUN NO.	1
MANDREL TEMP.	
EXTR. TIME	5.2 (NB)

PROCESSING DATA	PIECES CUT	CROPS-LENGTH	INSP. INITIALS	REMARKS

EXTRUSION LENGTH — OUTSIDE DIAMETER (FRONT MAX/MIN, REAR MAX/MIN) — INSIDE DIAMETER (FRONT MAX/MIN, REAR MAX/MIN) — WALL THICKNESS (FRONT MAX/MIN, REAR MAX/MIN): (blank)

BOW FULL LENGTH OR SECT. 1 / BOW FULL LENGTH ORIENTATION OR SECT. 2 / BOW SECT. A OR SECT. 3 / ORIENTATION SECT. A OR BOW SECT. 4 / INSP. INITIALS / REMARKS: (blank)

SHIPPING DATA — DATE PACKAGED / B/L NO. / BOX NO. / DESTINATION / TOTAL WEIGHT: (blank)

REMARKS
LENGTH 11'3¾"
LENGTH OF BUTT 2¾"
OD FRONT 0.860
OD MIDDLE 0.856

FIG 1

BEST AVAILABLE COPY

I. PRE-EXTRUSION PROCESSING

A. Inspection 100%

B. Surface Treatment Coat with GP-O + Heat in KBI supplied canister

II. EXTRUSION CONDITIONS

Probe CANISTER

A. Heating Conditions
1. Heating Furnace Type Sunbeam - 1600°F low fire billet temp
Temp. ______ Time-Max. ______ Min. 2 1/2 hrs.
2. Container Temp. ______ Indicator Set At 720°F
3. Tool Oven Temp. ______ Indicator Set At 600°F

Will advise of exact loading time.

B. Ram Speed 6.0 ipm

C. Estimated Force 1400 TONS

D. Extrusion Lubricant Fiske 604-D Modified

E. Extrusion Quench Air Cool

F. Extrusion Stamping Run # 1179

G. Health-Safety Required ______

H. Special Inspection Procedure diameter + length

III. POST EXTRUSION PROCESSING

A. Cutting
1. Finish Length Will Advise — None
2. Number of Samples None
3. Identification Stamp on Front Face
4. Diagram

B. Straightening None

C. Cleaning None

D. Pickling None

IV. SHIPPING AND ACCOUNTABILITY

A. Quality Requirements BEST EFFORTS
1. Addressee Kawecki Berylco Ind., Inc. Hazelton PA. 18201
2. Attention: Jim Atherton Beryllium Div. P.O. Box 429
3. Job Identification P.O.# H-30182
4. Special Container Description Package Protectively
5. Type of Carrier ~~Truck pickup available~~ Common

V. ACCOUNTABILITY

A. Extrusion Weights Obtain Gross

B. Forms 101 ______

C. Special Metals Packing List ______

D. Type of Scrap Disposal Ship with Extrusions

... Company

ASHTABULA EXTRUSION PLANT .FIG 3

P.O. BOX 579

ASHTABULA, OHIO

44004

PLANNED EXTRUSION PROJECT

WORK ORDER NO. 1561 EXTRUSION NO. U-1086 DATE 7-8-75

CUSTOMER Kawecki Berylco Ind, Inc. WORK AUTHORIZATION NO. OR PURCHASE ORDER NO. H-30182

MATERIAL Mild steel-clad Beryllium

OBJECTIVE To extrude rod.

EXTRUSION DETAIL:

NUMBER OF BILLETS 1 4.250 4.25

SIZE OF BILLETS ~~4.300~~" OD X ~~10.0~~ 8.0" Length

LINER DIAMETER 4.450" SS.E.S.

REDUCTION RATIO 26.2:1

DIMENSIONS OF EXTRUDED SHAPE: 0.869" dia. rod

NUMBER OF PIECES 1

DIFFICULTIES ANTICIPATED: Possible clad tearing

TOOLS OR EQUIPMENT TO BE PURCHASED BEFORE EXTRUSION: Minor Tooling

TENTATIVE EXTRUSION DATE 7-10-75, Thurs. 2nd Job

REMARKS: (Including Special Detail)

Commercial Order

SIGNATURE J. W. Hinkle

Fig 4 Thurs.

RMI NO. 1561 U NO. 1086 EXTRUSION DATE 7-10-75 ENGINEER Henderson

LINER SIZE 4.450" S.S.F.S.

△BI Mild Steel-Clad Beryllium 1 pc. to 0.869" dia. rod

TOOL NAME	NUMBER REQUIRED	PRINT NO.	TYPE NO.	OUTSIDE DIA.	INSIDE DIA.	THREAD SIZE	LENGTH	HARDNESS	REMARKS
BOLSTERS	1	[illegible]	30-53	11.730	2.500		4.625		
CONES	1	C-815	-1	4.440	1.583		1.429		
DIES	1	(DIH-3R1	-1	9.750	3.000		3.985		
	1	DI-114)	-1	3.000	0.869		1.500		
	1	A-1687		1.480	1.125		2.490	Filler piece	for
								relief of	DIH-3R1-1
DIE BACKERS									
DIE RINGS	1	DR-95		11.730	9.760		1.750		
DUMMY BLOCKS	1	DU-469	-4	4.440	Solid		3.0	1/2" x 45°	Chmf
MANDRELS									
BUTT SHEARING									
FOLLOWER BLOCKS									

SPECIAL EQUIPMENT & REMARKS:

Roller conveyor & Manco Shears

RUNOUT GUIDE NO. Rc.-144-2 = 1.660" x

REMARKS: 1.250" x 84.0"

( ) INDICATES ASSEMBLIES

Container No. 3856

Liner Holder No. 26-2

Liner No. 74-2

Stem No. ST-55-1 + SH-10-1 + ST-38-2

Die Head No. Insert

Mandrel Holder No. —

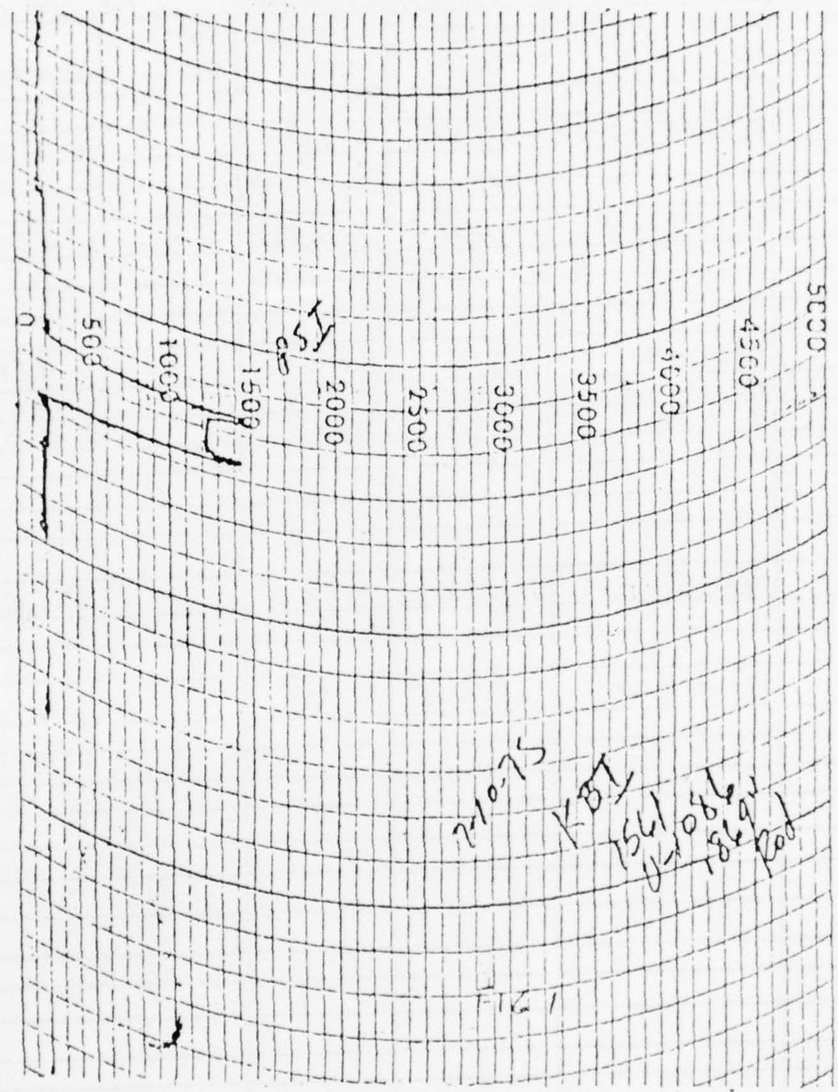
Repair Head No. —

Reducer Adapter No. —

Mand. Hold. Cooling Pipe No. and Size —

Cooling Pipe Connector No. —

Form No. 1046



TONNAGE = PSI X .776

FIG 5

KBI - Beryllium Billet No. XT1179 Date: 7-10-75

Low Fire Billet Temperature Check

Time	Temperature °F	Comments
Load:		
11:45 a.m	———	
12:00 a.m.	1510	
12:10 p.m.	1590	
12:20 p.m.	1595	
12:30 p.m.	1600	
12:40 p.m.	1600	
12:50 p.m.	1600	
13:00 p.m.	1600	
13:10 p.m.	1610	
13:20 p.m.	1600	
13:30 p.m.	1600	
13:40 p.m.	1600	
13:50 p.m.	1600	
14:00 p.m.	1600	
14:10 p.m.	1600	
14:30 p.m.	1600	
15:00 p.m.	1600	
15:10 p.m.	1600	

Signed: J. Atherton

Fig. 6

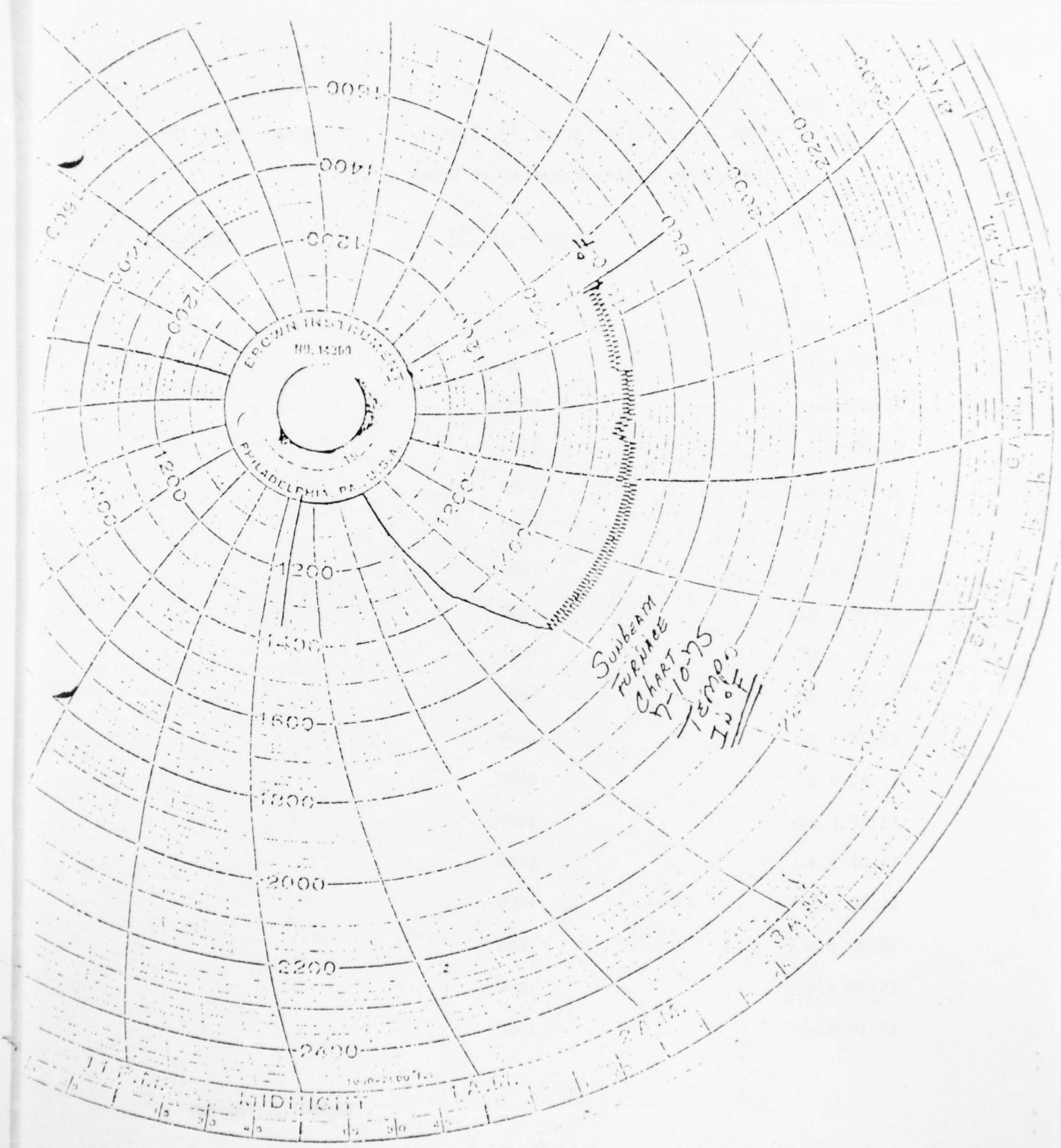

BROWN INSTRUMENT
NO. 14200
PHILADELPHIA, PA. U.S.A.
MIDNIGHT
Sunbeam
Furnace
Chart
7-10-75
Temp
In °F

Fig 7

Form # BH-1

STANDARD OPERATING PROCEDURE

KBI - HAZLETON PLANT

Prepared by	Date 9-11-75	Prod. Dept. Appr.	Date 9/18/75	Number: 614-310-05.002	Rev:
Mfg. Engr. Appr.	Date 9/18/75	Facil. Engr. Appr.	Date 9-19-75	Date Effective: 9/10/75	Page 1 of 2
Qual. Assur. Appr.	Date 9/18/75		Date 9/18/75	Plant Manager Appr.	Date 9/16/75

Title: Evacuation and copper spraying of KBI Billet Assembly ZHC-4117 Rev. B.

General Purpose:

Establishment of a standard method to be followed by production in the evacuating, sealing off and copper spraying of KBI Billet Assembly ZHC-4117 Rev. B.

Equipment:	Tooling:
Wheelabrator air blast equip. or sand blasting equip. -- Metco Type 2MC Plasma flame spray or Metco Type BC metallizing gun -- vac. system manifold with fore pump - Muffle type fce. with temperature controller	Copper powder or copper wire - aluminum oxide or sand - oxyacetylene torch - asbestos gloves - firebrick

If at any time an operator cannot follow the instructions contained herein, he MUST, (1) notify his foreman or supervisor of the problem as well as, (2) make a note of the problem on his run record and/or routing sheet. He SHOULD NOT take corrective action or alter his required operational techniques without first having supervisory permission. The exception to this rule would be emergency action to prevent, (a) personal injury, (b) loss of material, or, (c) equipment damage.

1.0 Procedure:

1.1 Place welded and leaked checked assembly into muffle type furnace allowing 3/8 inch diameter steel tubing to stick out approximately 25".

1.2 Affix evacuation tubes on vacuum system manifold. Start vacuum pump, open valves and evacuate to less than 10 microns.

1.3 Close door or seal opening around steel tube and turn furnace on, run for a minimum of 6 hours at $1650 {}^{+25}_{-0}$ °F. After 6 hours, if vacuum is 10 microns or less turn the power off leaving vacuum on.

1.4 Open furnace or remove seal around tube to permit rapid cooling of billet. Vacuum should be less than 10 microns before proceeding to 1.5.

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Plant Manager — Date 9/16/

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1.5 Remove billet still connected to the vacuum system to a flat table or floor. Place anvil under stem, approximately 1½" from face of tail plug. Using oxyacetylene torch heat a portion (3" long) of the steel tube above the anvil to a red heat. With a flat face hammer, flatten the heated portion of the tube. Adjust torch to maximum heat and point concentration and severe tube through center of flattened area by making a fusion weld.

1.6 Using either a Wheelabrator air blaster or sand blasting equipment, blast the O.D. with either aluminum oxide or sand to remove the oxidized steel and other contaminants.

1.7 Copper spray the O.D. six to ten mils on a side using either a Metco Type 2MC Plasma flame spray with Metco Type 55 powder or Metco Type BC metallizing green or thin equivalents.

Rev.	by	Date	Description

Form #~~[illegible]~~

STANDARD OPERATING PROCEDURE

KBI - HAZLETON PLANT

J. Calliston	9-11-75	[illegible]	9/18	Number: 614-310-05.003	R
Prepared by	Date	Prod. Dept. Appr.	Date	Date Effective: 9/10/75	Page 1
[illegible]	9/12/75	Blinker	9/11/75		
Mfg. Engr. Appr.	Date	Facil. Engr. Appr.	Date		
Paul C Kempster	9/18/75	J Wambold	9/11/75	N.K. Schoenly	9/16
Qual. Assur. Appr.	Date		Date	Plant Manager Appr.	Date

Title: Assemble and Welding of KBI Billet Assembly ZHC-4117 Rev. B

General Purpose:

Establishment of a standard method to be followed by production in assemblying and welding of KBI Billet Assembly ZHC-4117 Rev. B

Equipment:	Tooling:
P&G 400 ampere D.C.T.I.G. Welding Machine Welder Sales 300 ampere D.C.-A.C. welded machine. Consolidated helium leak detector Model 24-120 or equivalent	Welding shield or goggles - welding gloves liquid nitrogen - helium - welding rods E7018 oxyweld 65 or equivalent - steel stamps

If at any time an operator cannot follow the instructions contained herein, he MUST, (1) notify his foreman or supervisor of the problem as well as, (2) make a note of the problem on his run record and/or routing sheet. He SHOULD NOT take corrective action or alter his required operational techniques without first having supervisory permission. The exception to this rule would be emergency action to prevent, (a) personal injury, (b) loss of material, or, (c) equipment damage.

1.0 Procedure

1.1 Weld 3/8" diameter x .060 wall x 27" long low carbon steel tube (Item 4) to inner surface of Item 2 using TIG welding with Linde oxyweld 65 rod or equivalent.

1.2 Place inner surface or plug over orifice of leak detector. Seal O.D. of plug to top of leak detector with "Silly Putty" or equivalent. Plug end of tube opposite welded end and pump down assembly. Flood helium gas around tube where it projects from 2" long plug. While pulling vacuum on welded joint, no helium detected the welded joint is satisfactory. Remove plug from end of tube and remove part from leak detector.

1.3 Steel stamp XT number on outer surface of 2" long steel plug.

1.4 Glass bead blast I.D. of steel can Item 3, inner surfaces of Item 1 & 2, and all surfaces of Item 5 at a maximum pressure of 40 psi until all contamination is removed

1.5 Assemble per SOP 730-988-05.001 for solid billet, placing face of beryllium billet containing a horizontal piece of tantalum next to Item 1 or the nose of the assembly

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1.5 continued -- Place washer on other end of billet before inserting Item 2.

1.6 Locate plugs approximately 1/4" into both ends of assembly in contact with the beryllium billet and weld plugs into place using either manual shielded arc with E7018 rod or TIG weld with Linde Oxyweld 65 rod or equivalent.

1.7 Connect 3/8 inch diameter steel tube into helium leak detector. Pump down assembly and flood each welded joint with helium separately, no helium detected on the leak detector the assembly is welded satisfactorily.

Rev.	by	Date	Description

1.5 continued -- Place washer on other end of billet before inserting Item 2.

1.6 Locate plugs approximately 1/4" into both ends of assembly in contact with the beryllium billet and weld plugs into place using either manual shielded arc with E7018 rod or TIG weld with Linde Oxyweld 65 rod or equivalent.

1.7 Connect 3/8 inch diameter steel tube into helium leak detector. Pump down assembly and flood each welded joint with helium separately, no helium detected on the leak detector the assembly is welded satisfactorily.

Description

AD-A038 273 NORTHROP CORP NORWOOD MASS PRECISION PRODUCTS DEPT F/G 17/7
MICRO-ELECTROSTATIC GYRO (MESG). MESG SECOND SOURCE DEVELOPMENT--ETC(U)
AUG 76 W MERRITT, R WESTHAVER, K MILLO F33615-74-C-1105
UNCLASSIFIED PPD-E-76-10424 AFAL-TR-76-150 NL

2 OF 2
AD
A038273

END
DATE
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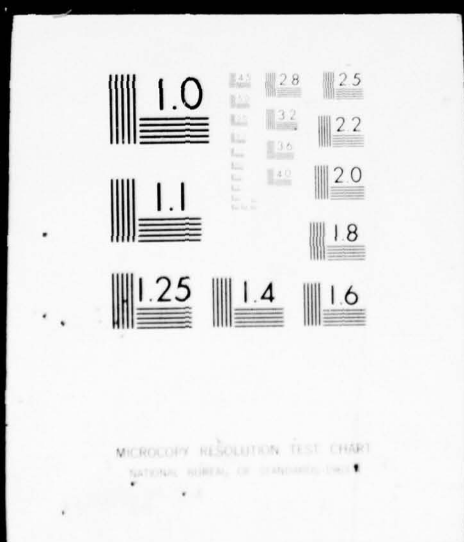
2 OF 2

AD A038273



Form #BH-1

STANDARD OPERATING PROCEDURE
KBI - HAZLETON PLANT

J E Etherton Jr. / Prepared by	9/24/74 / Date	[signature] / Prod. Dept. Appr.	10/3/74 / Date	Number: 640-999-05.002	Rev:
[signature] / Mfg. Engr. Appr.	10/3/74 / Date	B Kingree / Facil. Engr. Appr.	9/25/74 / Date	Date Effective: September 20, 1974	Page 1 of 4
H E Fuhrmeister / Qual. Assur. Appr.	9/30/74 / Date	J Wambold / L F Kelley 9/2/74	9/23/74 / Date	D K Schoenly / Plant Manager Appr.	10/2/74 / Date

Title:

Decladding of Lockalloy and Beryllium Extrusions

General Purpose:

This procedure covers the decladding of Lockalloy and Beryllium extrusions.

Equipment:	Tooling:
Stainless steel decladder & auxiliary equip. Drawings HB-5994-5-6-7 6" x 6" x 50" long fiberglas tray Spent acid tank - exhaust duct system Electric pump - Serfilco Model PP8200-BOP	Acid resistant gloves Acid resistant apron Soapstone Face shield

If at any time an operator cannot follow the instructions contained herein, he MUST, (1) notify his foreman or supervisor of the problem as well as, (2) make a note of the problem on his run record and/or routing sheet. He SHOULD NOT take corrective action or alter his required operational techniques without first having supervisory permission. The exception to this rule would be emergency action to prevent, (a) personal injury, (b) loss of material, or, (c) equipment damage.

1.0 General:

This procedure covers the decladding of lockalloy and beryllium extrusions.

2.0 Procedure:

2.1 Upon receipt of the cut extrusions from OSV, identity scribed on the end, Process Engineering will check and retain identity of parts to be declad against operation route sheet and forward information to Production Control.

2.2 Inspection will list all numbers on the routing sheet and issue the routing sheet to Production. NOTE: In some cases it will be necessary to have a separate routing for each piece. EXAMPLE: HUGHES TUBING.

2.3 Turn on light and exhaust system at decladder. (Figure 1 (HB-5995) is a schematic of the decladder showing location of valves and gages referred to in this SOP. Valves and gages are also labeled on the machine).

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Plant Manager Date

Official Copies:

A. Baymor E. Ferko	E. Fuhrmeister	B. Kingree	R. Leshko	W. Frauson J. Wambold	J. Atherton	D. Sterba
Prod. Supr.	Qual. Assur.	Facil. Engr.	Oper. Area		Originator	Document File

FORM # BH-1-A

STANDARD OPERATING PROCEDURE

KBI- HAZLETON PLANT

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640-999-05.002		2	4

2.4 Put on acid resistant apron, face shield and acid resistant gloves.

2.5 Check to make sure all valves are closed.

2.6 Open lid of decladder storage tank. Place water hose inside of storage tank, turn on water and fill tank to line marked on inside of tank (approx. 90 gallons).

2.7 Turn off water, remove hose, close all lids and securely fasten with toggle clamps. All valves on decladder should be closed.

2.8 If electrical pump is available, obtain same and proceed per Para. 2.9. If electrical pump is not available, proceed as per supplement at end of SOP.

2.9 Obtain electrical pump and extension cord from the electrical shop. Remove cap from 55 gallon drum of 42 Baume Nitric Acid. NOTE: NO ACID OTHER THAN NITRIC ACID SHOULD BE PUMPED INTO THE DECLADDER OR IT'S PUMPING SYSTEM. Flush pump throughly with water before using. Insert electrical pump intake into drum.

2.10 Place outlet hose into decladder storage tank. Close lid.

2.11 Plug into electrical outlet, start pump and pump until drum is empty.

2.12 Remove pump from drum and flush pump throughly with water. Remove outlet hose from decladder storage tank and rinse throughly.

2.13 Turn on Worthite pump. Open valve 'A' when pressure gage reads 10-15 pounds, then open valve 'C'.

2.14 Place material to be declad onto racks in decladder. Charge the following number of parts: (Maximum)

a) Lockalloy straps - 35, b) Lockalloy angles - 18, c) Beryllium clad with steel

2.15 Close and lock all lids.

2.16 If temperature of acid is not at 140-150°F, open main steam valve, outside of decladder enclosure and open valve in 'L'. When temperature reaches 140-150°F, close valve 'L' and main steam valve.

2.17 Close valve 'C'.

2.18 Open valve 'D'. Acid will now fill tank, come out over the overflow into the storage tank. Regulate valve 'D' to have a slight flow of acid over the overflow. If temperature of acid exceeds 175°F, or if heavy fumes are inside of decladder dump acid into storage tank as follows:

Quickly close valve 'A' and 'D' open 'G' and 'C', pumping acid into decladder storage tank. Allow to cool 140°F before pumping back into decladder.

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STANDARD OPERATING PROCEDURE
KBI- HAZLETON PLANT

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2.19 Allow to run 1-1½ hours.

2.20 Close valve 'A' and 'D'.

2.21 Open valve 'G' and 'C'. (acid will now flow back into the storage tank)

2.22 When decladder is empty, i.e. all acid is in storage tank. Stop Worthite pump. Open lid and rinse pieces with water. Drain rinse water into floor drain by opening large exit valve.

2.23 Turn parts 180°.

2.24 Close and lock all lids, closs all valves. Start Worthite pump.

2.25 Open valve 'A' and 'D'. Repeat steps 2.17 through 2.21.

2.26 Visually examine all pieces for steel on beryllium or copper on lockalloy. If all steel has been removed rinse, air dry and mark identification of piece on outside of part with soapstone. Send to decontamination for cleaning prior to sending to dimensional inspection. Pieces containing steel should be charged back into decladder with the next load. If all copper has been removed, proceed to step 2.26. If copper is still present on lockalloy, charge pieces back into decladder with the next load. If no other pieces are present, declad scrap pieces or put some iron into the solution.

2.27 In the fiberglas tank, mix up a solution by volume of 0.25% hydrofluoric acid - 25.0% nitric acid, remainder water. Immerse lockalloy parts into solution, if staining or discoloration occurs return to decladder. If staining or discoloration do not occur, rinse, air dry, and mark identification on outside surface of part with soapstone and send to dimensional inspection.

2.28 The acid added in 2.11 will normally take care of two loads of part. If it gets too weak, add approximately 20 gallons of acid per steps 2.8 through 2.12 and discard after two loads of parts have been declad, per para. 2.29.

2.29 To empty spend acid - all valves closed - start pump, close valves 'A' and 'D', open valves 'G' and 'C' pumping the acid into the decladder storage tank. Close valves 'G' and 'C'. If the temperature of the acid is below 130°F, open valve 'A' and when pressure gage reads 10-15 pounds open valve 'H'. After pumping out all acid, close valve 'H', close valve 'A' and stop pump.

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SUPPLEMENT TO SOP

STANDARD OPERATING PROCEDURE
KBI- HAZLETON PLANT

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FILLING OF DECLADDER WITH ACID USING DECLADDER PUMP

2.8 Remove cap from 55 gallon drum of 42 Baume Nitric Acid (NOTE: NO ACID OTHER THAN NITRIC ACID SHOULD BE PUMPED INTO THE DECLADDER OR IT'S PUMPING SYSTEM). Place acid intake line into acid drum.

2.9 Turn on Worthite pump.

210. Open valve 'A'. When pressure gage reads 10-15 pounds, open valve 'C'. Water will start circulating, wait a few minutes, open valve 'E'.

2.11 Slowly close valve 'A', acid will start pumping into the decladder storage tank. Pump approximately 55 gallons into decladder, second line on inside of tank. Close valve 'E'.

2.12 Open valve 'A'.

2.13 Remove inlet hose from acid drum and rinse off with water.

2.14 Place material.

3.0 Keep work area clean at all times and clean up area at completion of decladding operation.

3.1 Turn off light and exhaust system.

Superintendent and foremen shall enforce this procedure.

Distribution:

LVelky
PKempchinsky
Operators
Posting (1)

Rev.	by	Date	Description

Form #BH 1

STANDARD OPERATING PROCEDURE

KBI - HAZLETON PLANT

[signature]	10/13/75	[signature]	10/13/75	Number: 730-975-05.001	Rev:
Prepared by	Date	Prod. Dept. Appr.	Date	Date Effective: October 10, 1975	Page 1 of 4
[signature]	10/13/75	[signature]	10/13/75		
Mfg. Engr. Appr.	Date	Facil. Engr. Appr.	Date		
[signature]	10/13/75	[signature]	10/13/75	[signature]	10/13/75
Qual. Assur. Appr.	Date		Date	Plant Manager Appr.	Date

Title:

Etching of Beryllium Sheet and Extruded Products

General Purpose:

To define procedures and practices to be followed by production on etching of sheets and wrought products.

Equipment:

See below

Tooling:

If at any time an operator cannot follow the instructions contained herein, he MUST, (1) notify his foreman or supervisor of the problem as well as, (2) make a note of the problem on his run record and/or routing sheet. He SHOULD NOT take corrective action or alter his required operational techniques without first having supervisory permission. The exception to this rule would be emergency action to prevent, (a) personal injury, (b) loss of material, or, (c) equipment damage.

Equipment:

Etchant mixture--Master Mix prepared by the Chemistry Laboratory:

Tank I	Tank II	Tank III
34" x 47"	30" x 65"	38" x 105"
2" water - 52,000 c.c.	2" water - 64,000 c.c.	2" water - 130,000 c.c.
Master Mix - 3,650 c.c.	Master Mix - 4,550 c.c.	Master Mix - 9,100 c.c.

Master Mix as supplied by the laboratory will be in 2½ gallon plastic containers. Please return them to the laboratory when empty. A 4,000 c.c. graduated cylinder is provided for personnel mixing up tanks.

CAUTION: ALWAYS POUR ACID INTO WATER

Tanks and trays with existing exhaust hoods -- Wilgard rubber gloves 26-675 and small cloth gloves -- face shielf over safety glasses -- rubber apron -- Vidigage Model 21 thickness tester and 0-1" micrometer --

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Plant Manager | Date

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FORM # BH-1-A

STANDARD OPERATING PROCEDURE
KBI- HAZLETON PLANT

Number:	Rev:	Page of
730-975-05.001		2

Equipment Continued:

Respirator with yellow cartridge - Timer with sweep second hand - Baron Blakeslee Degreaser (Model HD-730 with appropriate racks) -- Demineralized water for tank make-ups and rinsing.

1.0 General:

This specification covers the etching of cross-rolled beryllium sheet and extruded products. It's intent is to define procedures and practices to be followed by production of the above products.

2.0 Procedure: (Etching .003 per side)

2.1 Make-up etchant tank to formula outlined above.

2.2 Obtain production sheet from inspection and record number to retain identity. Ascertain that sheet is within tolerance required before etching.

2.3 Put on rubber gloves.

2.4 Place a ground piece of beryllium end stock in tank and measure material removed in (5) minutes.

2.5 Clean sheet either with zyglo cleaner or by degreasing it in Baron Blakeslee Degreaser.

2.6 After the sheet is dry, examine it visually for defects such as pits, pimples, etc. and if defects are found bring it to the attention of the foreman, who should contact the Inspection Department.

2.7 Dip acceptable sheet into demineralized water, rinse and then place it into Tank I, II, III in the horizontal position, grasp sheet by edges and move it up an down in the acid. After ½ of the time calculated for etching, lift one corner of the sheet and measure it with micrometer. After measuring the sheet turn it over and etch it for the same period of time and measure it again. Repeat this operation until sheet is with specification.

2.8 Remove sheet from etching tank and rinse it by dipping several times into the rinse tank until no further action from the acid is seen.

2.9 Remove sheet from rinse tank and place on wooden blocks on grating. Wipe off smut using a cloth and lots of water carefully. Turn sheet over and repeat process.

2.10 Thoroughly rinse sheet on both sides using the hose with demineralized water.

2.11 Transfer sheet to the table where two 2" x 4" grooved wooden blocks are setting. Place long side of sheet in grooves of blocks allowing water to drain.

Rev.	by	Date	Description

2.12 Remove gloves and starting at top of sheet use Cadillac hot air blower and traverse towards bottom of sheet until one side is dry.

2.13 Using Kimwipes, grab end of sheet and turn it over so reverse side can be dried by repeating step 2.12.

2.14 While sheet is still in grooves in wooden blocks, using 0-1 inch micrometer determine thickness of sheet at all four corners and middle of sheet sides. If a .003" per side has been removed, wrap in brown paper and transport to inspection.

2.15 If less than .003" per side has been removed, calculate how much was removed in time allowed and place sheet back in tank for appropriate time to remove .003" per side repeating steps 2.14 through 3.1.

Caution; Beryllium sheet is susceptible to stains and precautions must be observed.

a. Wilgard rubber guards must be worn in handling the sheet and should be kept as clean as possible.

b. Each time gloves comes in contact with acid, rinse in water after completing the operation being carried out.

c. If gloves contact the sheet and rub the smut locally - do not re-etch until the whole sheet is cleaned of smut as outlines in 2.8 and 2.10, 2.11 and 2.12.

3.0 Maintenance of Etching Bath and Rinse Tank:

3.1 Add acid to the etching baths as follows:

3.1.1 Every shift before etching bring water level up to 2" and add acid as described below.

3.1.2 After etching the approximate square inches of beryllium sheet as prescribed below add acid as described below:

Tank I:	30" x 30" = 900 square inches
Tank II:	20" x 60" = 1200 square inches
Tank III:	30 " x 80" = 2400 square inches

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In either 3.1 or 3.12 add acid as follows:

Tank I: Master Mix - 600 c.c.

Tank II: Master Mix - 1000 c.c.

Tank III: Master Mix - 1650 c.c.

3.2 Demineralized water rinse tank should be dumped twice a week and cleaned out.

3.3 When using rinse tank allow a slow stream of water flowing into it to help skim top off.

3.4 Obtain production parts from inspection and record number to retain identity. Ascertain that parts are within tolerance.

3.5 Put on rubber gloves.

3.6 Clean parts with zyglo cleaner.

3.7 After the part is dry, examine it visually for defects, such as pits, pimples etc. If defects are found bring to the attention of the foreman, who should contact the Inspection Department.

3.8 Dip acceptable part into demineralized water rinse, and then place it into Tank I, II, III in horizontal position. If it is a flat part, allow it to etch for 1½ mins., turn it over and etch the other side 1½ minutes. If it is round, rotate it in the bath for three minutes.

3.9 Remove part from etching tank, rinse it by dipping several times in demineralized water until no further action takes place.

3.10 Wipe off smut using a cloth and lots of water.

3.11 Rinse in demineralized water.

3.12 Dry in air or by use of a hot air dryer.

Rev.	by	Date	Description

FORM # 311-1

STANDARD OPERATING PROCEDURE
KBI - HAZLETON PLANT

J. E. Atherton Jr.	9/4/73		9/4/73	Number: 730-988-05.001	Rev:
Prepared by	Date	Prod. Dept. Appr.	Date	Date Effective: September 4, 1973	Page 1 of 2
	9/4/73		9-4-73		
Mfg. Engr. Appr.	Date	Facil. Engr. Appr.	Date		
H.E. Fubmeste	9/4/73		9/4/73	D.K. Schoenly 9/4/73	
Qual. Assur. Appr.	Date		Date	Plant Manager Appr.	Date

Title:

Assembly of Extrusion Billets

General Purpose:

To define procedures and pratices to be followed for Assembly of Extrusion Billets

Equipment:	Tooling:
Baron B lakeslee Degreaser (Model HD-730 with appropriate racks) Rubber Gloves Small Cloth Gloves Assembly Table with Exhaust Hood Paper Towels - Zyglo Cleaner ZC-7	Steel Stamps Hammer Marking Pen Brown Paper Tape Paint Brushes of various sizes and lengths

If at any time an operator cannot follow the instructions contained herein, he MUST, (1) notify his foreman or supervisor of the problem as well as, (2) make a note of the problem on his run record and/or routing sheet. He SHOULD NOT take corrective action or alter his required operational techniques without first having supervisory permission. The exception to this rule, of course, would be emergency action to prevent, (a) personal injury, (b) loss of material, or, (c) equipment damage.

1.0 General:

This procedure covers the application of parting compound into various surfaces of extrusion assembly parts and the assembly of same.

2.0 Procedure:

2.1 Parting Compound Mix

PROPRIETARY MIXTURE

Mixture prepared by first mixing the dry powders, then pouring them into lacquer while stirring.

NOTE: The above mixture has attendancy to settle; therefore stir it before and while using it.

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Plant Manager Date

Official Copies:

G. Toczko

G. Toczko J. Wambold J. Atherton D. Jessel

2.2 Obtain beryllium billets, low carbon steel cans and plugs with appropriate paperwork from Inspection.

2.3 Place billets, cans and plugs into appropriate degreasing racks and degrease parts. Cool. Zyglo cleaner can be used as an alternative method for cleaning by spraying the article with zyglo and wiping dry with paper towels.

2.4 Steel Stamp XT numbers, at least 1/4" high, on plug containing vent hole according to data issued by Production Control.

2.5 Mix parting compound as outlined above in 2.1.

2.6 Tape inside and outside of can to an approximate depth of 1/4" to prevent parting compound on these surfaces to allow easier and better welded joints.

2.7 Apply one coat of parting compound, by brushing, onto surfaces indicated in Table I.

2.8 Air dry.

2.9 Apply second coat of parting compound.

2.10 Air dry.

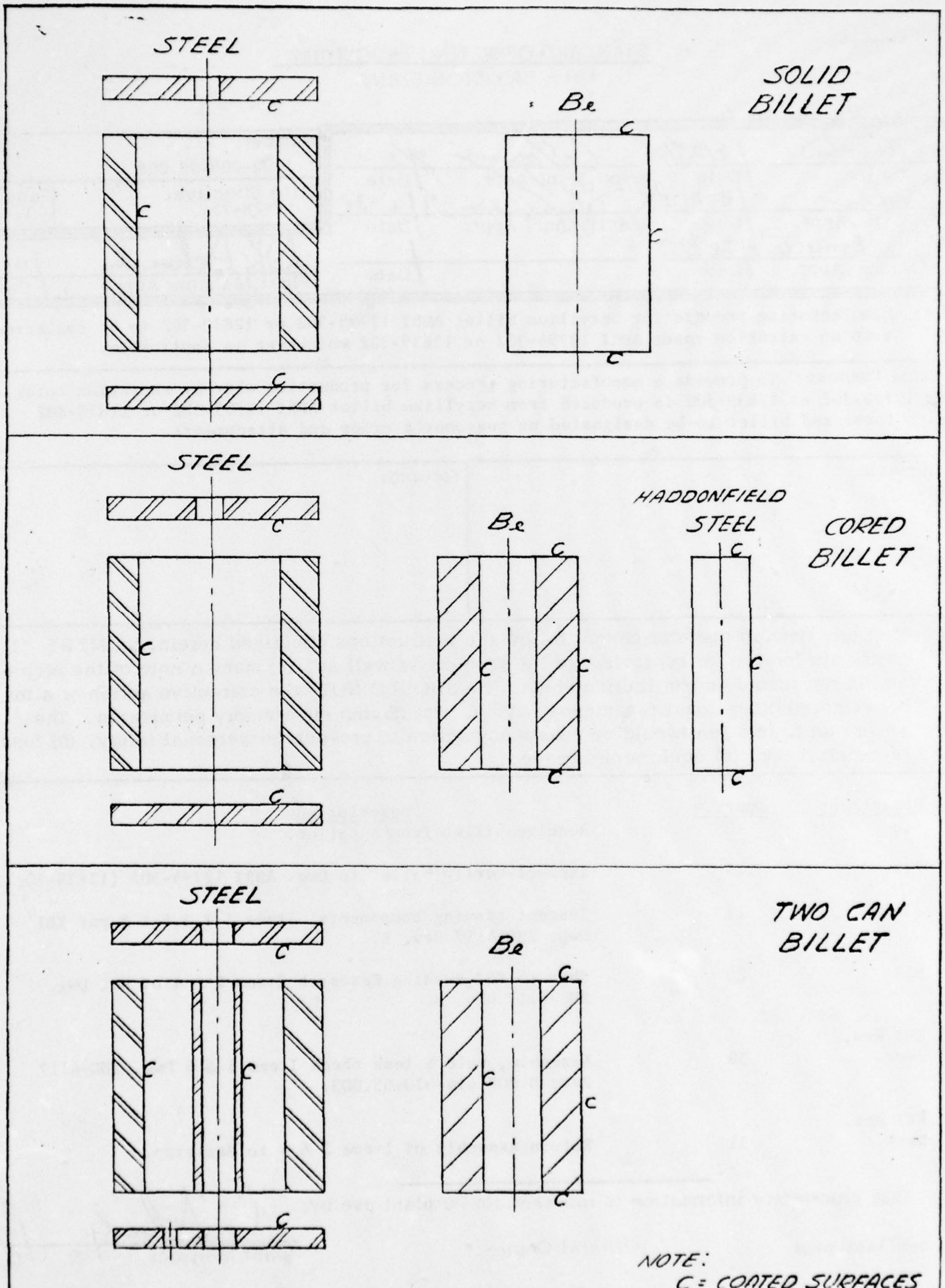
2.11 Check that vent hole is open.

2.12 Place beryllium billet inside of can. In case of the "two canned billet," place small diameter tube inside of beryllium billet. Place plugs in both ends, tape to hold.

2.13 Wrap in brown paper, mark XT number on paper and tape paper securely.

2.14 Take to shipping for shipment to OSV.

Rev.	by	Date	Description


STEEL
SOLID
BILLET
Be
C
STEEL
HADDONFIELD
STEEL
CORED
BILLET
Be
C
STEEL
TWO CAN
BILLET
Be
C
NOTE:
C = COATED SURFACES

Form #BH-1

STANDARD OPERATING PROCEDURE
KBI - HAZLETON PLANT

J E Atherton / Prepared by	8/28/75 / Date	C. Gryznez / Prod. Dept. Appr.	9/2 / Date	Number: 1200-000-08.008	Rev:
[signature] / Mfg. Engr. Appr.	8/28/75 / Date	[signature] / Facil. Engr. Appr.	9/2-75 / Date	Date Effective: 8-28-75	Page 1 of 2
H E Dukmeister / Qual. Assur. Appr.	8/28/75 / Date	/	Date	D K Schoenly / Plant Manager Appr.	10/13/75 / Date

Title: Manufacturing process for beryllium billet ADRI 12795-302 or 12838-302 to be converted into an extrusion rotor ADRI 12796-302 or 12839-302 whichever is applicable.

General Purpose: To provide a manufacturing process for production whereby extrusion rotor ADRI 12796-302 or 12839-302 is produced from beryllium billet ADRI 12795-302 or 12838-302 (which rotor and billet to be designated on customer's order and attachment).

Equipment:

Tooling:

If at any time an operator cannot follow the instructions contained herein, he MUST, (1) notify his foreman or supervisor of the problem as well as, (2) make a note of the problem on his run record and/or routing sheet. He SHOULD NOT take corrective action or alter his required operational techniques without first having supervisory permission. The exception to this rule would be emergency action to prevent, (a) personal injury, (b) loss of material, or, (c) equipment damage.

Department	Oper. #	Description
616	10	Receive billet from supplier.
735	15	Inspect-verify billet to Dwg. ADRI 12795-302 (12838-302).
735	25	Inspect canning components, Items 1,2,3,4 & 5 per KBI Dwg. ZHC-4117 Rev. B.
611	26	Ship to KBI Reading Research Items 2 & 4 of KBI Dwg. ZHC-4117 Rev. B.
KBI Res. Dept.	30	Assemble, weld & leak check Items 2 & 4 Dwg. ZHC-4117 Rev. B SOP 614-310-05.003.
KBI Res. Dept.	31	Return assembly of Items 2 & 4 to Hazleton.

This proprietary information is released for outplant use by:

C. K. Schoenly 10/13/75
Plant Manager / Date

See last page

Official Copies:

Prod. Supr. Qual. Assur. Facil. Engr. C-102 Originator

FORM # BH-1-A

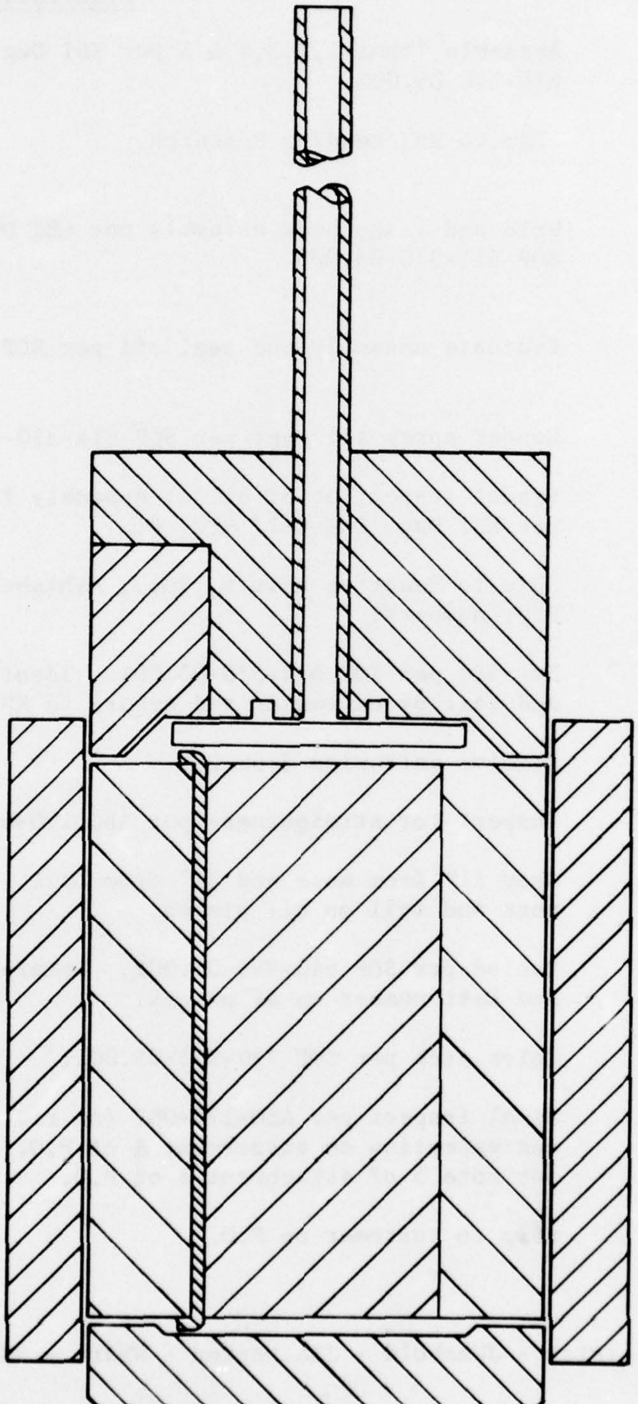
STANDARD OPERATING PROCEDURE
KBI- HAZLETON PLANT

Number: 1200-000-08.008	Rev:	Page 2	of 2

Department	Oper. #	Description
730	40	Assemble Items 1,2,3,4 & 5 per KBI Dwg. ZHC-4117 Rev. B and SOP 614-310-05.003.
611	41	Ship to KBI Reading Research.
KBI Res. Dept.	50	Weld and leak check assembly per KBI Dwg. ZHC-4117 Rev. B & SOP 614-310-05.003.
KBI Res. Dept.	60	Evacuate assembly and seal off per SOP 614-310-05.002.
KBI Res. Dept.	70	Copper spray all over per SOP 614-310-05.002.
735	75	Visual inspection of billet assembly for copper spray coating per KBI Dwg. ZHC-4117 Rev. B.
611	80	Ship to Reactive Metals, Inc., Ashtabula, Ohio referencing P.O. numbers.
OSV	90	Extrude per SOP 614-310-05.001. Identify heat number, nose and tail of extrusion and return to KBI Hazleton.
616	100	Receive extrusion from OSV.
735	105	Inspect for straightness per ABO 170-067 (no. rev.) Para. 3.2.2
730	110	Crop 11" from nose and 33" from tail. Identify with heat number nose and tail on all pieces.
640	120	Declad per SOP 640-999-05.002. Retain identify of nose, tail and heat number on al pieces.
730	121	Color etch per SOP 730-975-05.001.
735	125	Final inspect per ABO-170-067 (no rev.) per Para. 3.2.2; 3.2.3 and exception on attachment A of P.O. (note 2), 3.2.4 and x-ray per note 5 of attachment A of P.O.
611	130	Ship to customer on P.O.

Distribution - HEFuhrmeister - JWambold - JEAtherton - WMarz - SGoldstein

Rev.	by	Date	Description



Extrusion Billet Assembly
KBI Dwg. ZHC-4117, Rev. B

6A517-15

Appendix D

CSDL Tests Results

The Charles Stark Draper Laboratory, Inc.

68 Albany Street, Cambridge, Massachusetts 02139 Telephone (617) 258- 4095

18 March, 1976
JJM-17

Mr. F. A. Hallock
Northrop Corporation
Electronics Division
100 Morse Street
Norwood, MA 02062

Reference: Northrop P.O. 26907, CSDL Account 70222

Dear Mr. Hallock:

Regarding the above purchase order, you will find enclosed our report on the micro-yield strength of two specimens of extruded beryllium plus the tabluated data.

Very truly yours,

John J. McCarthy

JJM/nlc
Attachments

CC:

J. Palmieri
J. Stemniski
J. Lanfranchi (Contracts Office)

12 March, 1976
JJM-17

MICRO-YIELD STRENGTH OF EXTRUDED BERYLLIUM

Purpose

Two specimens of extruded beryllium were tested to determine the 2×10^{-6} offset micro-yield strength.

Results

The values of 2×10^{-6} offset micro-yield strength and modulus of elasticity (E) are:

Sample Number	MYS (2×10^{-6} offset) (psi)	E (psi)
1	24,500	42.1×10^6
2	16,000	43.0×10^6

Specimen Preparation

Specimens were supplied to C. S. Draper Lab machined to drawing SK 740060 (Figure 1). The specimens were tested in the "as-machined" condition; they were not stress relieved or chemically etched.

Two epoxy-backed foil strain gages (Micro-Measurements MA-06-125AD-120) were installed on each specimen. They were located at mid-length, parallel with the center line, and oriented at 180^o to each other. The gages were cemented with M-Bond-600 epoxy cement using a pressure and cure schedule recommended by the manufacturer (Micro-Measurements) for transducer applications.

Test Procedure

The tests were conducted on a CSDL-designed lever type testing machine using a standard load-unload method. Strain rate was approximately .025 inches/inch/min. for loading and unloading. Full

load was maintained only long enough to record loaded strain (approximately 1 minute). The specimen remained unloaded for 1 to 2 minutes between load increments.

Strain measurements were made by means of BLH Electronics Model 1200 Digital Strain Indicator. The sensitivity of the instrument was 1 micro-strain and the maximum apparent drift during the tests was 2 micro-strain. The two strain gages of the specimen under test were connected as opposite arms of a full bridge configuration; the gages on the second specimen, which served as a temperature compensator, completed the bridge. With this arrangement, the indicated strain was equal to twice the average actual strain.

The compensating specimen was located in close proximity to the active specimen and both were enclosed in a styrofoam box to reduce temperature fluctuations. The specimens were allowed to equilbrate in temperature for several hours before the test was started; test temperatures were 82° and 78°F, respectively.

Results

The stress-residual strain curves are shown as Figure 2 and 3. The modulus of elasticity was calculated from the elastic portion of the stress-strain curve.

John J. McCarthy
Metallurgist

JJM/nlc
Attachments

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Results

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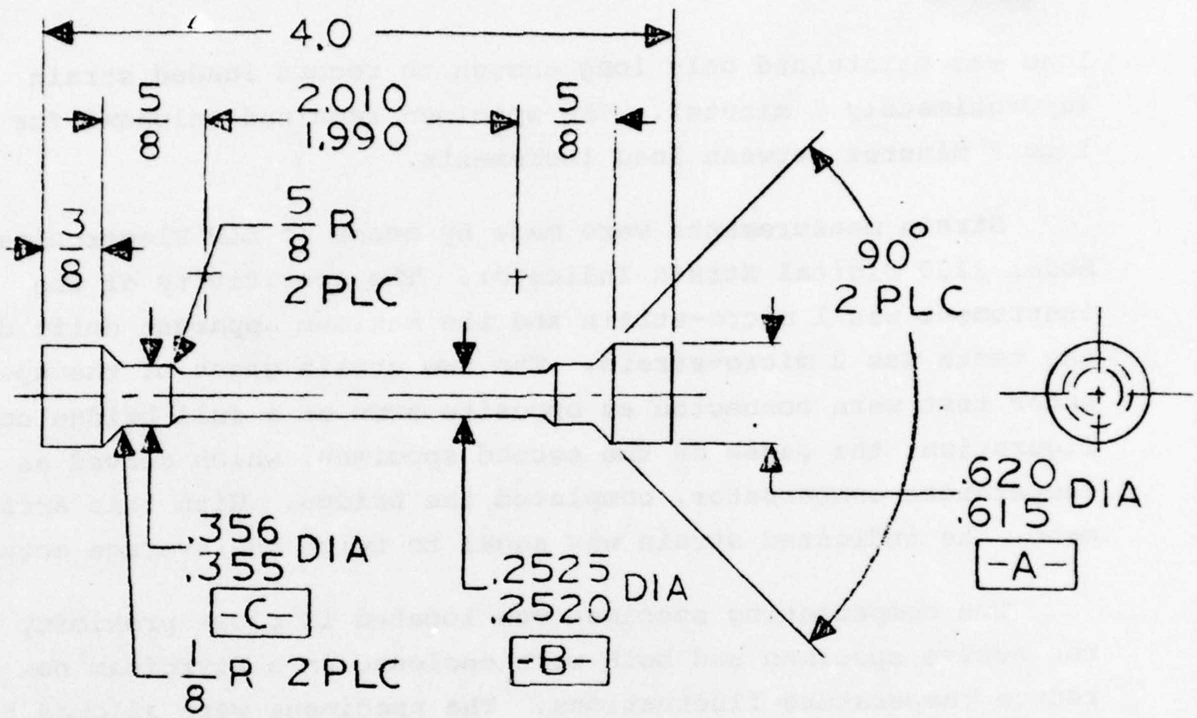
John J. McCarthy
Metallurgist

JJM/nlc
Attachments

FIG. 1

APPLICATION		REVISIONS				
NEXT ASSEMBLY	USED ON	LTR	DESCRIPTION	DWN	DATE	APPROVED



NOTES:

1. DIA'S -A- -B- AND -C- TO BE ◎ .0005 TIR
2. BOTH 90° TAPERS TO BE ◎ B .0001 TIR
3. 5/8 AND 1/8, R TO BE TANGENT WITH THEIR RESPECTIVE DIA'S WITH NO STEP
4. CENTERS OPTIONAL

REVISION STATUS	REV
	SHEET

UNLESS OTHERWISE SPECIFIED
CAPACITOR VALUES ARE IN μF
RESISTOR VALUES ARE IN OHMS
DIMENSIONS ARE IN INCHES
TOLERANCE ON
DECIMALS .XX ± .XXX ±
ANGLES ±
DO NOT SCALE THIS DRAWING
MATERIAL

CONTRACT NO.
DRAWN R Vaughan 9/10/74
CHECKED
APPROVED
APPROVED
CSDL APPROVED DATE
APPROVED
BY DIRECTION

THE CHARLES STARK DRAPER LABORATORY, INC.
CAMBRIDGE, MASSACHUSETTS, 02139

MYS TENSILE SPECIMEN

SIZE	CODE IDENT NO.	DRAWING NO.	REV
A	51993	SK740060	

SCALE 2x | SHEET 1 OF

FIG. 2

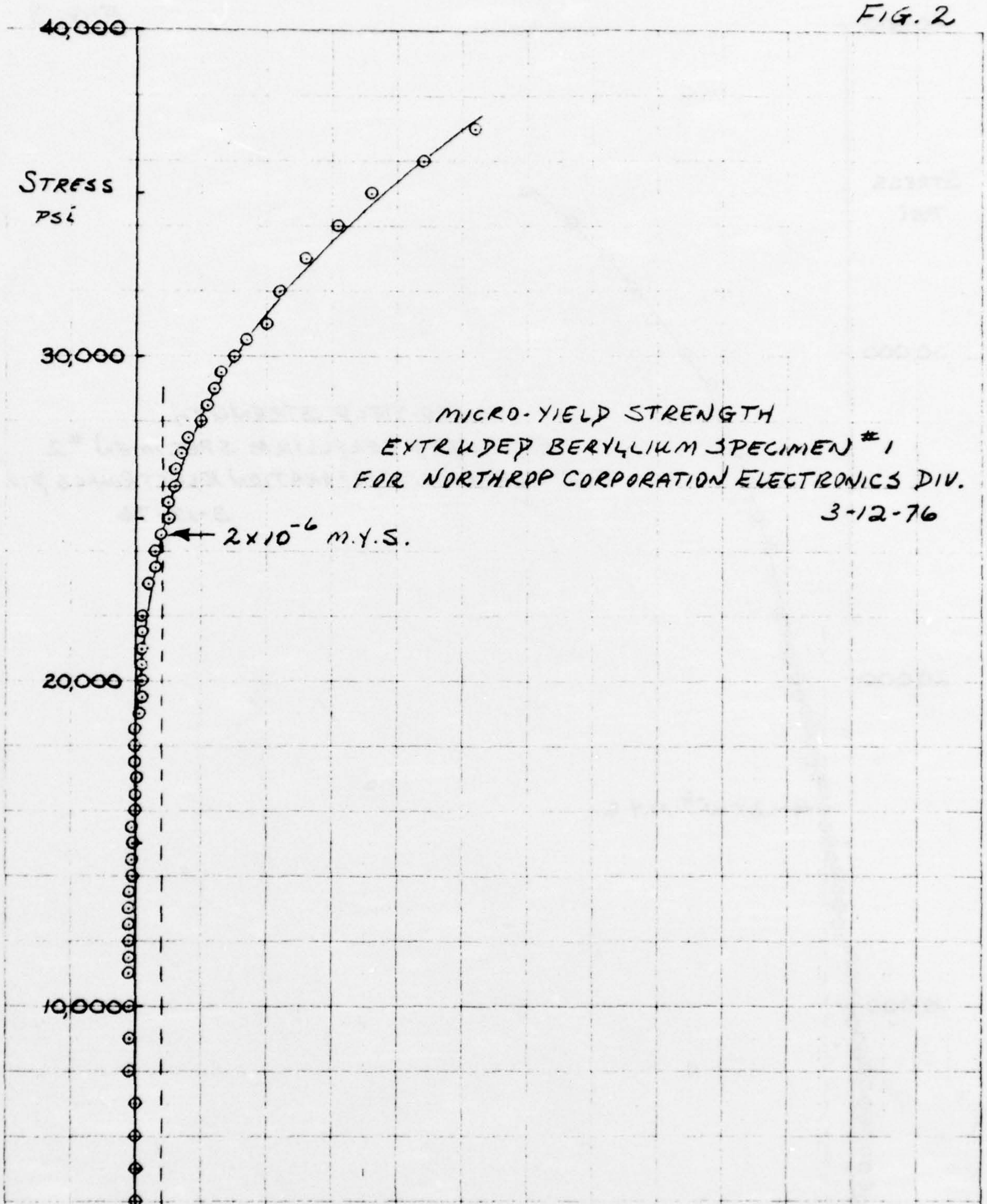
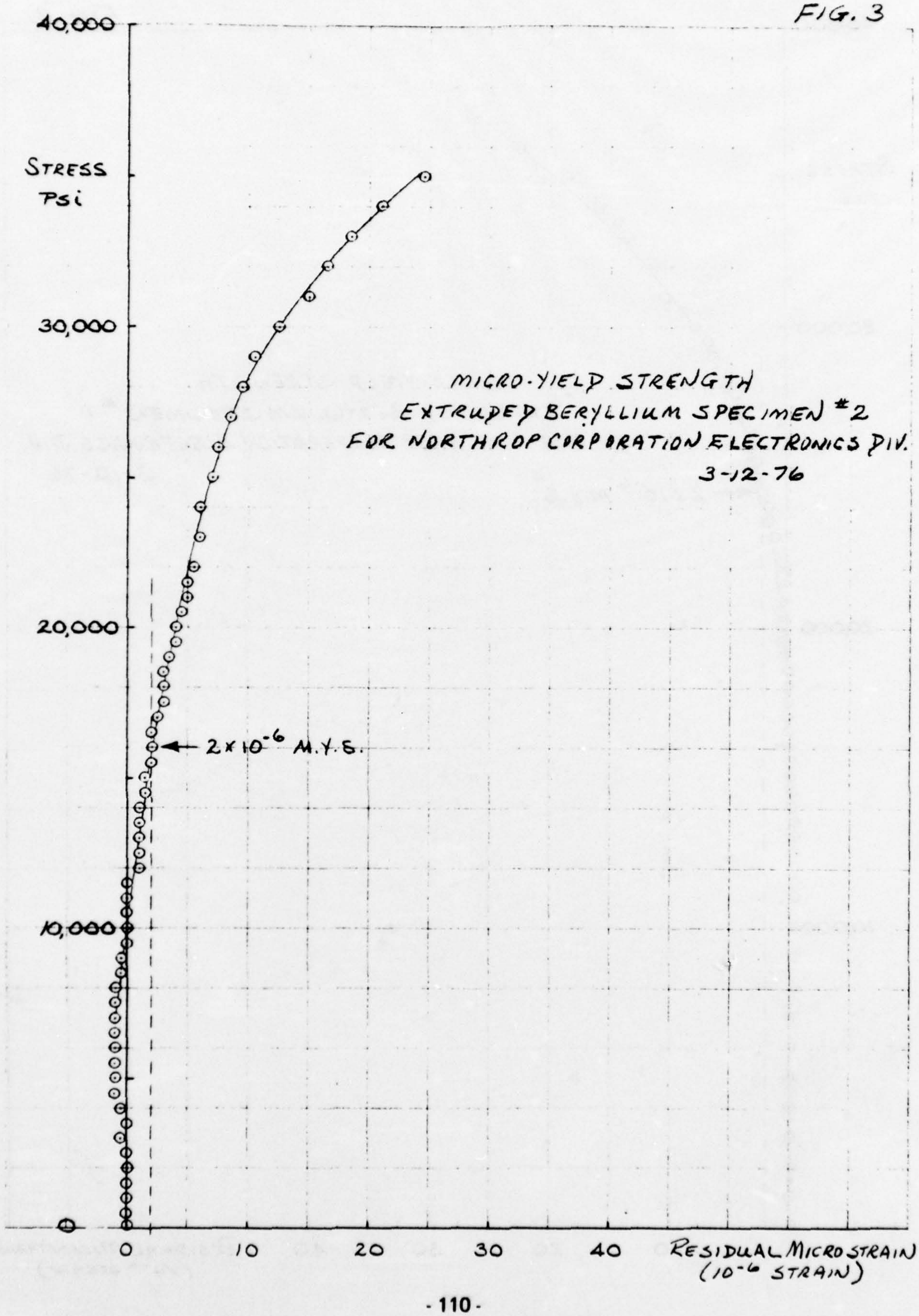

40,000
30,000
20,000
10,0000
STRESS
PSI
MICRO-YIELD STRENGTH
EXTRUDED BERYLLIUM SPECIMEN #1
FOR NORTHROP CORPORATION ELECTRONICS DIV.
3-12-76
2x10^-6 M.Y.S.
0
10
20
30
40
RESIDUAL MICROSTRAIN
(10^-6 STRAIN)

FIG. 3



40,000
30,000
20,000
10,000
STRESS
PSi
MICRO-YIELD STRENGTH
EXTRUDED BERYLLIUM SPECIMEN #2
FOR NORTHROP CORPORATION ELECTRONICS DIV.
3-12-76
2×10⁻⁶ M.Y.S.
0
10
20
30
40
RESIDUAL MICRO STRAIN
(10⁻⁶ STRAIN)

WEIGHT OF LOWER GRIPS. 6.245 lbs
SPEC. AREA = .05 Sq. in.

NORTHROP CONTRACT NO. 26907

P.E.L. TEST METALLURGY GROUP

SPECIMEN NO. #1
MATERIAL Beryllium S200 EXTRUDED
DATE 2/20/76
TECHNICIAN D.M.S

GAGE FACTOR 2.105 ± 0.5%
GAGE TYPE MA-06-125 AD

TIME	LOAD lbs.	STRESS P.S.I.	NO-LOAD S.I. R'DING	LOADED S.I. R'DING	Δ RES. STRAIN	Δ LOADED STRAIN	TEMP.	
					PLASTIC	TOTAL		
	6.245	@ 125	2500.5		0	0		
	50	1,000	2500.5	2458.5	0	49÷2=24.5		
	100	2,000	2500.5	2409.5	0	91÷2=45.5		
	150	3,000	2500.6	2360.5	0	140÷2=70		
	200	4,000	2500.5	2313	0	187.5÷2=93.7		
	250	5,000	2500.5	2265.5	0	235÷2=		
	300	6,000	2500.5	2218	0	282÷2=141		
	350	7,000	2500.5	2170.5	0	330÷2=165		
	400	8,000	2501.5	2123.5	1÷2=.5	377÷2=188.5		
	450	9,000	2501.5	2075.5	1÷2=.5	425÷2=212.5		
	500	10,000	2501.5	2028.5	1÷2=.5	472÷2=236		
	~~[illegible]~~	~~10,500~~		~~[illegible]~~				

T.P. # 4876

P.E.L. TEST METALLURGY GROUP

SPECIMEN NO. #1
MATERIAL S200 Be EXTRUDED
DATE 2/28/76
TECHNICIAN D.M.S

GAGE FACTOR 2.105 ± 0.5%
GAGE TYPE MA-06-125AD

TIME	LOAD lbs.	STRESS psi	NO-LOAD S.I. R'DING	LOADED S.I. R'DING	Δ RES. STRAIN	Δ LOADED STRAIN	TEMP.	
					PLASTIC	TOTAL		
	550	11,000	2501.5	1980.5	1÷2=.5	520÷2=260		
	575	11,500	2501.5	1956.5	1÷2=.5	544÷2=272	81°F	
	600	12,000	2501.5	1932.5	1÷2=.5	568÷2=284		
	625	12,500	2501.5	1908.5	1÷2=.5	592÷2=296		
	650	13,000	2501.5	1885.5	1÷2=.5	615÷2=307.5		
	675	13,500	2501.5	1859.5	1÷2=.5	641÷2=320.5		
	700	14,000	2501	1835.5	.5÷2=.25	665÷2=332.5		
	725	14,500	2501	1811.5	.5÷2=.25	689÷2=344.5		
	750	15,000	2501	1787.5	.5÷2=.25	713÷2=356.5		
	775	15,500	2501	1764	.5÷2=.25	736.5÷2=368.2		
	800	16,000	2500.5	1738.5	0	762÷2=381		
	825	16,500	2500.5	1714.5	0	786÷2=393		

P.E.L. TEST METALLURGY GROUP

SPECIMEN NO. #1
MATERIAL S200 Be. EXTRUDED
DATE 2/20/76
TECHNICIAN DMS

GAGE FACTOR 2.105 ±0.5%
GAGE TYPE MA-06-125AD

TIME	LOAD lbs.	STRESS P.S.I.	NO-LOAD S.I. R'DING	LOADED S.I. R'DING	Δ RES. STRAIN	Δ LOADED STRAIN	TEMP.	
					PLASTIC	TOTAL		
	850	17,000	2500.5	1690.5	0	810÷2=405		
	875	17,500	2500.5	1665.5	0	835÷2=417.5		
	900	18,000	2500.5	1642.5	0	858÷2=429		
	925	18,500	2500.5	1618.5	0	882÷2=441		
	950	19,000	2500	1594.5	.5÷2=±.25	906÷2=453		
	975	19,500	2499.5	1572.5	1÷2=±.5	928÷2=464		
	1,000	20,000	2499.5	1551.5	1÷2=±.5	949÷2=474.5	81.5	
	1025 ~~1050~~	20,500	2499.5	1524.5	1÷2=±.5	976÷2=488		
	1050 ~~1100~~	21,000	2499.5	1503.5	1÷2=±.5	997÷2=498.5		
	1075 ~~1150~~	21,500	2499.5	1478.5	1÷2=±.5	1022÷2=511		
	1100 ~~1200~~	22,000	2499.5	1458.5	1÷2=±.5	1042÷2=521		
	1125 ~~1250~~	22,500	2499	1437.5	1.5÷2=±.75	1066÷2=533.5		

P.E.L. TEST METALLURGY GROUP

SPECIMEN NO. #1
MATERIAL Be S200 EXTRUDED
DATE 2/20/76
TECHNICIAN DMS

GAGE FACTOR 2.015 ± 0.5%
GAGE TYPE

TIME	LOAD LBS.	STRESS PSI	NO-LOAD S.I. R'DING	LOADED S.I. R'DING	Δ RES. STRAIN PLASTIC	Δ LOADED STRAIN TOTAL	TEMP.	
	1150	23,000	2498.5	1410.5	2÷2=1	1090÷2=545		
	1175	23,500	2497.5	1386.5	3÷2=1.5	1114÷2=557		
	1200	24,000	2497.5	1361.5	3÷=1.5	1139÷2=569.5		
	1225	24,500	2496.5	1334.5	4÷2=2	1166÷2=583		
	1250	25,000	2495.5	1312.5	5÷2=2.5	1188÷2=594		
	1275	25,500	2495.5	1289.5	5÷2=2.5	1211÷2=605.5		
	1300	26,000	2494.5	1265.5	6÷2=3	1235÷2=617.5		
	1325	26,500	2494.5	1242.5	6÷2=3	1258÷2=629		
	1350	27,000 ~~27,500~~	2493.5	1212.5	7÷2=3.5	1288÷2=644		
	1375	27,500 ~~28,000~~	2492.5	1191.5	8÷2=4	1309÷2=654.5		
	1400	28,000 ~~28,500~~	2490.5	1167.5	10÷2=5	1335÷2=667.5		
	1425	28,500 ~~29,500~~	2489.5	1142.5	11÷2=5.5	1358÷2=679		

T.P. # 4876

P.E.L. TEST METALLURGY GROUP

SPECIMEN NO. #1
MATERIAL Be S 200 EXTRUDED
DATE 2/20/76
TECHNICIAN DMS

GAGE FACTOR
GAGE TYPE

TIME	LOAD	STRESS	NO-LOAD S.I. R'DING	LOADED S.I. R'DING	Δ RES. STRAIN	Δ LOADED STRAIN	TEMP.	
					PLASTIC	TOTAL		
	1450	29,000 ~~30,000~~	2488.5	1117.5	12÷2=6	1383÷2=691.5		
	1475	29,500 ~~30,500~~	2487.5	1091.5	13÷2=6.5	1409÷2=704.5		
	1500	30,000 ~~31,000~~	2485.5	1063.5	15÷2=7.5	1437÷2=718.5		
	1525	30,500 ~~31,500~~	2483.5	1042.5	17÷2=8.5	1458÷2=729		
	1550	31,000 ~~32,000~~	2480.5	1010.5	20÷2=10	1490÷2=745		
	1600	32,000 ~~33,000~~	2478.5	962.5	22÷2=11	1548÷2=774		
	1650	33,000 ~~34,000~~	2474.5	912	26÷2=13	1588.5÷2=794.2		
	1700	34,000 ~~35,000~~	2469.5	859	31÷2=15.5	1641.5×2=820.7		
	1750	35,000 ~~36,000~~	2464.5	800	36÷2=18	1700.5÷2=850.2		
	1800	36,000 ~~37,000~~	2456.5	744	44÷2=22	1756.5÷2=878.2		
	1825	37,000 ~~38,000~~	2448.5	696	52÷2=26	1809.5÷2=904.7	82°F	

T.P. # 4876

WEIGHT OF LOWER GRIP 6.245 lbs.

SPEC. DIA. #1 0.2522"
GAGE AREA #2 0.2522"

P.E.L. TEST METALLURGY GROUP

SPECIMEN NO. #2 NORTHRUP CONTRACT NO. 26907
MATERIAL ~~EXTRUDED~~ BERYLLIUM S200
DATE 2/18/76
TECHNICIAN DMS

#2 DO FIRST IN GRIPS

GAGE FACTOR 2.105 ± 0.5%
GAGE TYPE MA-06-125AD

STRAIN INDICATOR READING DECREASES WITH INCREASING STRAIN

TIME	LOAD lbs	STRESS PSI	NO-LOAD S.I. R'DING	LOADED S.I. R'DING	Δ RES. STRAIN	Δ LOADED STRAIN	RES STRAIN ~~TEMP.~~ PLASTIC	STRAIN TOTAL
					PLASTIC ÷ GAGE	TOTAL GAGE		
	WEIGHT OF 6.245 GRIPS	125	3400		0	0 DIVIDE BY 2	0	0
	25	500	3400	3382	0	18	0	9
	50	1000	3400	3359	0	41	0	20.5
	75	1500	3400	3336	0	64	0	32
	100	2000	3400	3312	0	88	0	44
.05 in² SPEC. AREA.	125	2500	3400	3289	0	111	0	55.5
	150	3000	3401	3266	-1	134	-0.5	67
78°F	175	3500	3400	3242	0	158	0	79
	200	4000	3401	3219	-1	181	-0.5	90.5
	225	4500	3401	3197	-1	203	-1	101.5
	250	5000	3401.5	3174	-1.5	226	-1	113
	275	5500	3401.5	3151	-1.5	249	-1	124.5

T.P. # 4876

P.E.L. TEST METALLURGY GROUP

SPECIMEN NO. #2
MATERIAL S200 BERYLLIUM EXTRUDED
DATE 2/18/76
TECHNICIAN DMS

GAGE FACTOR 2.105 ± 0.5%
GAGE TYPE

TIME	LOAD	STRESS	NO-LOAD S.I. R'DING	LOADED S.I. R'DING	Δ RES. STRAIN	Δ LOADED STRAIN	TEMP. PLASTIC	TOTAL STRAIN
	300	6,000	3401.5	3128	-1.5	272	-1	136
	325	6,500	3401.5	3104	-1.5	293	-1	146.5
	350	7,000	3401.5	3081	-1.5	319	-1	159.5
	375	7,500	3401.5	3057	-1.5	343	-1	171.5
	400	8,000	3401.5	3033	-1.5	367	-1	183.5
	425	8,500	3401	3009	-1	391	-0.5	195.5
	450	9,000	3401	2986	-1	414	-0.5	207
	475	9,500	3400	2962	0	438	0	219
	500	10,000	3399.5	2939	+.5	461	0	230.5
775°F		10,500	3399.5	2916	+.5	484	0	242
		11,000	3399.5	2892	+.5	508	0	254
		11,500	3399.5	2868	+.5	532	0	266

T.P. # 4876

P.E.L. TEST METALLURGY GROUP

SPECIMEN NO. #2 GAGE FACTOR
MATERIAL S 200 BERYLLIUM EXTRUDED GAGE TYPE
DATE 2/18/76
TECHNICIAN

TIME	LOAD	STRESS	NO-LOAD S.I. R'DING	LOADED S.I. R'DING	Δ RES. STRAIN	Δ LOADED STRAIN	RES. STRAIN ~~TEMP.~~ PLASTIC	TOTAL STRAIN
		12,000	3398.5	2843	+1.5	557	+1	278.5
		12,500	3398.5	2819	+1.5	581	+1	290.5
		13,000	3398.5	2798	+1.5	602	+1	301
		13,500	3398	2774	+2	626	+1	313
		14,000	3397.5	2748	+2.5	652	+1	326
		14,500	3397	2723	+3	677	+1.5	338.5
		15,000	3397	2701	+3	699	+1.5	349.5
		15,500	3396.5	2677	+3.5	723	+2	361.5
		16,000	3396	2651	+4	749	+2	374.5
		16,500	3396	2629	+4	771	+2	385.5
		17,000	3395	2606	+5	794	+2.5	397
		17,500	3394.5	2583	+5.5	817	+3	408.5

T.P. # 4876

P.E.L. TEST METALLURGY GROUP

SPECIMEN NO. #2
MATERIAL S200 Be EXTRUDED
DATE 2/18/75
TECHNICIAN DMS

GAGE FACTOR
GAGE TYPE

TIME	LOAD	STRESS PSI	NO-LOAD S.I. R'DING	LOADED S.I. R'DING	Δ RES. STRAIN	Δ LOADED STRAIN	TEMP. PLASTIC STRAIN	TOTAL STRAIN
		18,000	3394.5	2556	+5.5	844	+3	422
		18,500	3394	2531	+6	869	+3	434.5
		19,000	3393.5 3393.5	2510 2508 2509	+6.5	891	+ 3.5	445.5
		19,500	3392.5	2492	+7.5	908	+4	454
		20,000	3392 3392	2482 2464	+8	936	+4	468
		20,500	3391.5	2438	+8.5	962	+4.5	481
		21,000	3390.5	2413	+9.5	987	+5	493.5
		21,500	3390	2392	+10	1008	+5	504
		22,000	3389.5	2369	+10.5	1031	+5.5	516
		22,500						
	→	23,000	3388.5	2319	+11.5	1081	+6	540.5
		23,500						

T.P. # 4876

P.E.L. TEST METALLURGY GROUP

SPECIMEN NO. #2
MATERIAL Be S200 EXTRUDED
DATE 7/13/71
TECHNICIAN DMS

GAGE FACTOR
GAGE TYPE

TIME	LOAD	STRESS	NO-LOAD S.I. R'DING	LOADED S.I. R'DING	Δ RES. STRAIN	Δ LOADED STRAIN	TEMP. ELASTIC STRAIN	TOTAL STRAIN
		24,000	3388	2271	+12	1129	+6	564.5
		25,000	3386.5	2218	+13.5	1182	+7	591
		26,000	3385	2170	+15	1230	+7.5	615
		27,000	3383	2126	+17	1274	+8.5	637
		28,000	3381	2075	+19	1325	+9.5	664.5
		29,000	3379	2027	+21	1373	+10.5	686.5
		30,000	3375.5	1978	+24	1422	+12.5	711
		31,000	3370.5	1924	+29.5	1472	+15	738
		32,000	3367.5	1876	+32.5	1524	+16.5	762
		33,000	3363.5	1825	+36.5	1575	+18.5	787.5
		34,000	3358.5	1773	+41.5	1627	+21	813.5
		35,000	3351.5	1719	+48.5	1681	+24.5	840.5

T.D. # 4876

The Charles Stark Draper Laboratory, Inc.

68 Albany Street, Cambridge, Massachusetts 02139 Telephone (617) 258-

13 April, 1976
JJM-21

Mr. F. A. Hallock
Northrop Corporation
Electronics Division
100 Morse Street
Norwood, MA 02062

Reference: Northrop P. O. 26906, CSDL Account 70221

Dear Mr. Hallock:

Regarding the above purchase order, you will find enclosed our report on the thermal expansion of beryllium and beryllium-oxide samples. Tabulated data is also enclosed.

Very truly yours,

John J. McCarthy
Metallurgist

JJM/nlc
Attachments

cc:

J. Palmieri
J. Stemniski
J. Lanfranchi

THERMAL EXPANSION OF BERYLLIUM AND BERYLLIUM-OXIDE FROM 95 TO 210F

Purpose

Thermal expansion was determined as a function of temperature for specimens of beryllium and beryllium-oxide. Values were determined in the radial direction for the beryllium-oxide specimen and in the radial and longitudinal directions for the beryllium specimen.

Results

Coefficients of thermal expansion for the temperature interval 95 to 210F are as follows:

Sample	Coefficient of Thermal Expansion (95 to 210F)
Beryllium Oxide	2.91×10^{-6} Per ^{o}F
Beryllium (Longitudinal)	7.9×10^{-6} Per ^{o}F
Beryllium (Radial)	6.5×10^{-6} Per ^{o}F

Expansion is also plotted as a function of temperature.

Specimen Preparation

Specimens were supplied to C. S. Draper Lab in the form of right circular cylinders; they were tested as received. The beryllium specimen was 5/8 inch diameter by 5/8 inch long; the beryllium-oxide specimen was 0.7 inch diameter by 0.3 inch long.

Epoxy-backed foil strain gages (Micro-Measurements MA-06-125AD-120) were used to measure expansion. Two gages were installed on the beryllium specimen, one on the outer diameter with the gage axis parallel to the axis of the cylinder, the other centered on the transverse surface. A single gage was installed on the transverse surface of the beryllium oxide sample. The gages were

bonded with M-Bond-600 epoxy cement; they were wired with a 3-wire arrangement.

Test Procedure

The strain gage method for determining coefficient of expansion is described by W. T. Bean[1]. The test specimen of known thermal expansion characteristics was N.B.S. Standard Reference Material 731 (Borosilicate Glass). Strain gages from the same lot were installed on the standard reference material and the specimen under test. An N.B.S. calibrated thermometer was used for temperature measurement instead of individual temperature sensors.

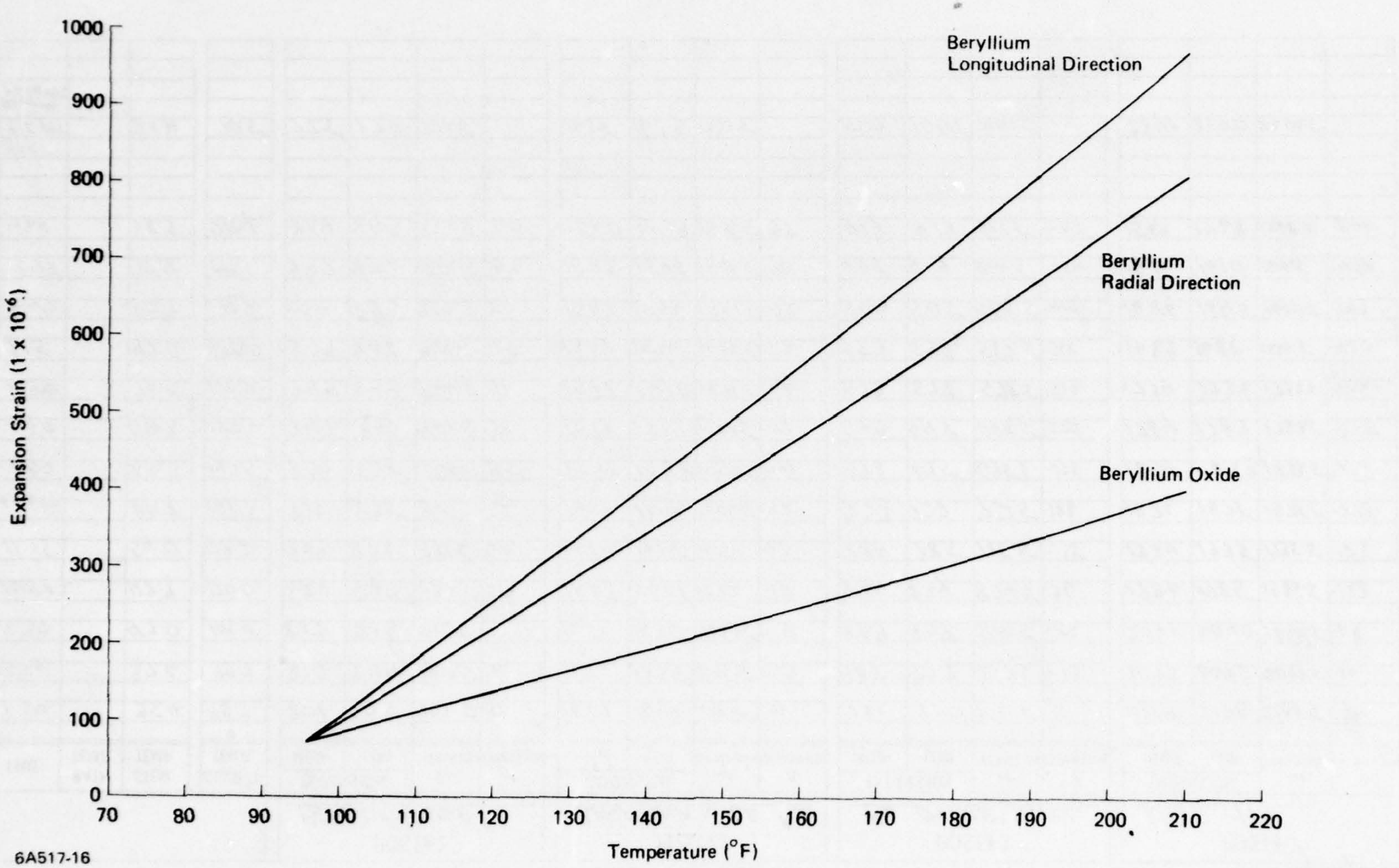
The specimens under test and the standard reference material were tied to the thermometer with the strain gages located close to the bulb. The assembly was immersed in a silicone oil bath which was stirred and temperature controlled by means of a Haake Type EC Thermostat.

The strain gages were connected in a quarter-bridge configuration through a low resistance switch box to a BLH Model 1200 Digital Strain Indicator using a 3-wire hook-up. The specimens were temperature stabilized in the oil bath over night at the first test temperature. Strain gage readings were taken for the standard reference material and the test specimens and the temperature was recorded. The thermostat was then re-set to the next test temperature. The heating rate was approximately $1^{\circ}F$ per minute and the test temperature was held constant for 10 minutes before taking readings.

(1) "Linear Thermal Expansion Coefficient of Materials Measured with Strain Gages", W. T. Bean, Strain Gage Readings, Vol. V No. 5; Dec. - Jan. 1962-63.

Using the method described in reference 1, a gage characteristics curve was constructed from the standard reference material strain gage readings. Working from this curve and the apparent strain readings from the test specimens, an expansion curve was constructed for each test specimen. The expansion curves are attached as Figure 1. The coefficient of thermal expansion was calculated from the expansion curve using the following equation:

$$\alpha_{T_1 T_2} = \frac{\Delta \text{Strain}_{T_2 T_1}}{T_2 - T_1}$$



6A517-16

Figure 1.
Thermal Expansion
Beryllium and Beryllium Oxide
(Strain Gage Method)

BEST AVAILABLE COPY

CHARGE # PEL — 70222
THERMAL EXP. — 70221

80°F TO 210°F
10° INTERVALS

THERMAL EXPANSION

DATE 3/19/76

					POST#1 BERYLLIUM GAGE #1				POST#2 BERYLLIUM GAGE #2				POST#3 Be OXIDE DISC				POST#4 NBS HT			
	TIME	BATH TEMP.	STEM TEMP.	CORR. °F TEMP.	EXPANSION HIGH	EXPANSION LOW	AVE. EXPANSION	Δ EXPANSION	EXPANSION HIGH	EXPANSION LOW	AVE. EXPANSION	Δ EXPANSION	EXPANSION HIGH	EXPANSION LOW	AVE. EXPANSION	Δ EXPANSION	EXPANSION HIGH	EXPANSION LOW	AVE. EXPANSION	Δ EXPANSION
71°F	9:30		35.4	95.7	804	803	803.5	0	1639	1638	1638.5	0	921	920	920.5	0	2109	2108	2108.5	0
	10:00		37.6	99.7	810	809	809.5	6	1636	1635	1635.5	-3	908	907	907.5	-13	2093	2092	2092.5	-16
RT 71°F	10:30		43.0	109.4	817	816	816.5	13	1631	1630	1630.5	-8	869	868	868.5	-52	2041	2040	2040.5	-68
	10:50		48.9	120.0	824	823	823.5	20	1623	1621	1622	-17	825	824	824.5	-96	1986	1985	1985.5	-123
71°F	11:15		54.0	129.2	829	828	828.5	25	1616	1615	1615.5	-23	786	785	785.5	-135	1936	1935	1935.5	-123
	12:10		60.7	141.3	836	835	835.5	32	1607	1606	1606.5	-32	733	732	732.5	-188	1876	1875	1875.5	-233
71°F	1:00		65.3	149.5	839	838	838.5	35	1599	1598	1598.5	-40	696	695	695.5	-225	1834	1833	1833.5	-275
	1:30		70.8	159.4	842	841	841.5	38	1588	1587	1587.5	-51	649	648	648.5	-272	1784	1783	1783.5	-325
	1:50		76.8	170.2	845	844	844.5	41	1577	1576	1576.5	-62	599	598	598.5	-322	1734	1732	1732.5	-376
	2:15		82.2	180.0	849	848	848.5	45	1567	1566	1566.5	-72	553	552	552.5	-368	1689	1688	1688.5	-420
	2:40		87.9	190.2	854	853	853.5	50	1557	1556	1556.5	-82	506	505	505.5	-415	1646	1645	1645.5	-463
	3:10		92.8	199.1	857	856	856.5	53	1549	1548	1548.5	-90	465	464	464.5	-456	1611	1610	1610.5	-498
	4:00		98.9	210.1	864	863	863.5	60	1540	1539	1539.5	-99	414	413	413.5	-507	1569	1568	1568.5	-540
R.T. CHECK 70.5°F	3/22/76 8:15 AM NO MIXING OF WATER		21.4	70.5	775	774	774.5		1634	1633	1633.5		1010	1009	1009.5		2241	2240	2240.5	

THERMAL EXPANSION

DATE ____

TIME	BATH TEMP.	STEM TEMP.	CORR. °F TEMP.	POST#~~1~~5 NBS GLASS EXPANSION HIGH	POST#~~1~~5 NBS GLASS EXPANSION LOW	POST#~~1~~5 AVE. EXPANSION	POST#~~1~~5 Δ EXPANSION	POST#2 EXPANSION HIGH	POST#2 EXPANSION LOW	POST#2 AVE. EXPANSION	POST#2 Δ EXPANSION	POST#3 EXPANSION HIGH	POST#3 EXPANSION LOW	POST#3 AVE. EXPANSION	POST#3 Δ EXPANSION	POST#4 EXPANSION HIGH	POST#4 EXPANSION LOW	POST#4 AVE. EXPANSION	POST#4 Δ EXPANSION
	°C																		
9:35	35.4		95.7	4221	4220	4220.5	0												
	37.6		99.7	4211	4210	4210.5	-10												
10:30	43.0		109.4	4172	4171	4171.5	-49												
	48.9		120.0	4126	4125	4125.5	-95												
	54.0		129.2	4086	4085	4085.5	-135												
12:14	60.7		141.3	4036	4035	4035.5	-185												
	65.3		149.5	3998	3996	3997	-223.5												
1:30	70.8		159.4	3950	3948	3949	-271.5												
	76.8		170.2	3898	3896	3897	-323.5												
2:15	82.2		180.0	3851	3847	3849	-371.5												
2:40	87.9		190.2	3804	3803	3803.5	-417												
3:10	92.8		199.1	3756	3753	3754.7	-465.8												
4:00	98.9		210.1	3703	3700	3701.5	-519												

Appendix E

Letter from Coors Porcelain Company

COORS PORCELAIN COMPANY

GOLDEN, COLORADO 80401

(303) 279-6565

July 17, 1975

Northrup Nortronics
Division of the Northrup Corp.
100 Morse Street
Norwood, Mass.

BEST AVAILABLE COPY

Attention: Purchasing Dept.

Gentlemen:

COORS PORCELAIN COMPANY has produced beryllium oxide products for approximately fifteen years. As you might or might not know, the operation has not contributed to profits. To the contrary, it has consistently operated at a loss. In our opinion, as we project raw material costs, the ever increasing need for environment protection and other costs attendent to manufacturing beryllium oxide products, the future looks less and less attractive.

Although we intend to maintain a facility capability to supply our own internal needs - primarily related to our metallizing operation - in view of the above, we have decided to discontinue the manufacture of beryllium oxide products for customers other than ourselves just as soon as practicable.

You have been, and we hope you will continue to be, a valued customer of COORS PORCELAIN COMPANY. While we suspect this decision comes as a surprise to you, we want to minimize any potential disruption to your operations. In order to give you time to qualify other sources we will accept any orders you wish to place for products we have manufactured in the past through August 29th. The one condition that we would impose on those orders is that they be scheduled for delivery no later than December 24, 1975.

We regret the fact that it is necessary to drop the product line. It has not been a decision that was made easily. We have, in fact, debated it for a considerable amount of time. Having reached that decision our prime concern now is to minimize the impact on you while

July 17, 1975
Page Two

at the same time achieving our goal of eliminating production of product for outside customers as soon as possible. We hope that approaching it as outlined above will accomplish that goal.

I trust that we will be able to continue the relationship we have enjoyed for many years in serving you in our other product lines.

Very truly yours,

COORS PORCELAIN COMPANY

C. E. Nordquist

C. E. Nordquist - cel
Vice President
Sales and Marketing

BEST AVAILABLE COPY

Appendix F

Mass. Dept. of Labor Beryllium Notice

BERYLLIUM

HAZARD CLASSIFICATION HIGHLY TOXIC--USE EXTREME PRECAUTIONS WHEN DUST OR FUME IS PRESENT.

GENERAL Beryllium occurs naturally in the mineral beryl, a beryllium aluminum silicate. Metallic beryllium in a pure state is expensive but is employed in guidance control and optical instrumentation, propulsion (solid rocket fuel), structures, X-ray tube windows and certain other nuclear and scientific applications.

Copper-beryllium and other alloys containing up to 5% beryllium are being extensively used for a variety of industrial purposes in automotive products, computers and business machines, electronics, process industries, communication, aerospace, power distribution equipment and in tools and special equipment.

Beryllium oxide is a good conductor of heat and an electrical insulator. It is used in the manufacture of ceramics, in parts for the electronics industry, crucibles and thermal coatings. It finds applications in the nuclear industry and in special individual plastics.

Special beryllium compounds find a minor use in intermetallic compounds, such as organics, chemicals, and at one time was an ingredient of the coating in fluorescent tubing employed for lamps and signs.

The most active beryllium compounds are water-soluble salts, such as the sulfate and the fluoride. Dust and fumes from beryllium metal, beryllium alloys, and finely divided beryllium oxide are also harmful. So far as is known, there is little hazard associated with the handling of the naturally-occurring beryllium mineral, beryl.

HARMFUL EFFECTS (1) PULMONARY

(A) Acute. A relatively brief exposure to high concentrations of beryllium dust or fume may be followed by sudden shortness of breath, cough, cyanosis, fever, chest pain, and an X-ray picture resembling pneumonia. This acute form of the disease, if not fatal, subsides usually in one to three months. If the worker returns to the same occupational environment, recurrent episodes may ensue.

(B) Chronic. In the chronic or delayed form of the illness, the symptoms may develop at any time from a few months to years after the last exposure. The onset is gradual, with loss of weight, loss of appetite, shortness of breath, and cough. X-ray films will show a characteristic pattern of nodular changes. The course is protracted and usually but not always progressive. Death in those severely affected and not properly treated follows a period of progressive weight loss, shortness of breath, and heart failure.

(2) SKIN. Skin lesions caused by beryllium and certain of its compounds are:

(A) Contact dermatitis and skin ulcers.

(B) Subcutaneous granulomas resulting from beryllium particles penetrating the skin appear as localized small tumors which disappear when the foreign material is removed.

MAXIMUM ALLOWABLE CONCENTRATION For continuous exposure over an eight-hour period, two micrograms (0.002 milligram) beryllium per cubic meter of air.

PROTECTIVE MEASURES All operations giving off dust or fume of beryllium or its compounds should be enclosed or supplied with effective local exhaust ventilation.

Handling of beryllium oxide or beryllium powder should be done in a booth ventilated at not less than 200 cfm. per square foot of opening. If noticeable dust is produced, an enclosed dry box should be used if practicable.

Although the melting of copper-beryllium alloy produces very little beryllium fum a ventilated hood over the furnace is recommended.

High-speed machining operations with beryllium at cut-off wheels, surface grind and centerless grinders should be enclosed as much as possible and exhaust ventilated at not less than 200 cfm. p square foot of opening.

Milling, drilling, polishing and similar machining operations of beryllium should b provided with local exhaust ventilation so as to produce a control velocity of 150 fpm. at the point of operatio Beryllium alloys usually do not require special ventilation for machining operations, but dry grinding and polishin processes should be exhausted.

In the grinding of beryllium alloys, the grinding wheel should be hooded i accordance with the bulletin entitled, "Standard Hoods for Grinding, Buffing and Polishing", published by th Division. The air volumes exhausted should be at least 25% greater than those specified for regular grinding.

For operations of short duration involving exposure to beryllium dust, approve air-line respirators or filter-type respirators approved for use against highly toxic dust or fumes may be worn.

MEDICAL CONTROL Personnel working with beryllium or its compounds should be under close medica supervision, with particular attention to lungs, skin and general health. Once berylliosis o the lungs has been recognized, removal from exposure and, where indicated, steroid therapy are required.

MASSACHUSETTS DEPARTMENT OF LABOR AND INDUSTRIES
DIVISION OF OCCUPATIONAL HYGIENE

No. 1024 • Supersedes No. 903 December, 1971
Publication approved by Alfred C. Holland, State Purchasing Agent - No. 11

Appendix G

MESG Final Data Packages (PPD)

and

AGRI Metrology Measurements

ELECTROSTATIC GYROSCOPE

MICRON

FINAL DATA PACKAGE

Control S/N NA 11

Rotor P/N 12504-302 Rev 1 (3-28-75)

					Q.A.	Date
1)	Major Dia. 405570±.000005	is .405570	AT 68°			1-2-76
2)	Minor Dia. 405540±.000010	is .405541	AT 68°			1-2-76
3)	Surface Finish	is Not Specified	AT °			
4)	Roundness Requirements	is Not Specified	AT °			

DCASR 1-2-76

ELECTROSTATIC GYROSCOPE

MICRON

FINAL DATA PACKAGE

Control S/N NA 14

Rotor P/N 12504-302 Rev 1 (3-28-75)

				Q.A.	Date
1)	Major Dia. 405570±.000005	is .405566	AT 68°	A64	2/11/76
2)	Minor Dia. 405540±.000010	is .405540	AT 68°	A64	2/11/76
3)	Surface Finish	is Not Specified	AT °		
4)	Roundness Requirements	is Not Specified	AT °		

DCASR 2/11/76

Form-ESG-M-1 (1/30/75)

ELECTROSTATIC GYROSCOPE

MICRON

FINAL DATA PACKAGE

Control S/N NA 16

Rotor P/N 12504-302 Rev 1 (3-28-75)

					Q.A.	Date
1)	Major Dia. 405570±.000005	is .405568	AT	68°		1-2-76
	Minor Dia. 405540±.000010	is .405538	AT	68°		1-2-76
3)	Surface Finish	is Not Specified	AT	°		
4)	Roundness Requirements	is Not Specified	AT	°		

DCASR 1-2-76

ELECTROSTATIC GYROSCOPE

MICRON

FINAL DATA PACKAGE

Control S/N NA 22

Rotor P/N 12504-302 Rev 1 (3-28-75)

					Q.A.	Date
1)	Major Dia. 405570±.000005	is .405573	AT	68°	A64	2/11/76
2)	Minor Dia. 405540±.000010	is .405547	AT	68°	A64	2/11/76
3)	Surface Finish	is Not Specified	AT	°		
4)	Roundness Requirements	is Not Specified	AT	°		

DCASR 2/11/76

orm-ESG-M-1 (1/30/75)

ELECTROSTATIC GYROSCOPE

MICRON

FINAL DATA PACKAGE

Control S/N Z/13

Rotor P/N 12504-302 Rev Orig

				O.A.	Date
1) Major Dia. 405570±.000005	is .405568	AT 68 °		AG4	5-7-75
2) Minor Dia. 405540±.000010	is 405540	AT 68 °		AG4	5-7-75
3) Surface Finish	is Not Specified	AT °		N/A	
4) Roundness Requirements	is Not Specified	AT °		N/A	

DCASR

-1-1-V-1 (1/30/75)

ELECTROSTATIC GYROSCOP

MICRON

FINAL DATA PACKAGE

Control S/N Z 16

Rotor P/N 12504-302 Rev Orig

				Q.A.	Date
) Major Dia. 405570±.000005	is .405571	AT 72.8		[illegible]	1-31-75
Minor Dia. 405540±.000010	is .405543	AT 72.5	°	[illegible]	1-31-75
) Surface Finish	is Not Specified	AT	°		
) Roundness Requirements	is Not Specified	AT	°		

DCASR

2/4/75

ELECTROSTATIC GYROSCOPE

MICRON

FINAL DATA PACKAGE

Control S/N Z 18

Rotor P/N 12504-302 Rev Orig

					Q.A.	Date
1.	Major Dia. 405570±.000005	is .405572	AT	72°		2/21/75
2)	Minor Dia. 405540±.000010	is .405545	AT	72°		2/21/75
3)	Surface Finish	is Not Specified	AT	°		
4)	Roundness Requirements	is Not Specified	AT	°		

DCASR 2-27-75

Form-ESG-M-1 (1/30/75)

ELECTROSTATIC GYROSCOPE

MICRON

FINAL DATA PACKAGE

Control S/N Z- 20

Rotor P/N 12504-302 Rev Orig

					Q.A.	Date
) Major Dia. 405570±.000005	is .405571 (~~564~~ 566)	AT 71 69	°F	A64	3-19-75
) Minor Dia. 405540±.000010	is .405544 (~~536~~ 539)	AT 71 69	°F	A64	3-19-75
) Surface Finish	is Not Specified	AT	°	NA	-
Roundness Requirements	is Not Specified	AT	°	NA	-

DCASR C5I5 4/4/75

Perfect

ELECTROSTATIC GYROSCOPE

MICRON

FINAL DATA PACKAGE

Control S/N Z 21

Rotor P/N 12504-302 Rev Orig

						Q.A.	Date
1)	Major Dia. 405570±.000005	is .405 568 (565)	AT	70 (69)	°F	A64	3-20-75
2)	Minor Dia. 405540±.000010	is .405 538 (535)	AT	70 (69)	°F	A64	3-20-75
3)	Surface Finish	is Not Specified	AT		°	N/A	
4)	Roundness Requirements	is Not Specified	AT		°	N/A	

DCASR 4/4/75

1 Dwg (D)

SPD-ESG-M-1 (1/20/75)

ELECTROSTATIC GYROSCOPE

MICRON

FINAL DATA PACKAGE

Control S/N Z-22

Rotor P/N 12504-302 Rev Orig

				Q.A.	Date
Major Dia. 405570±.000005	is .405573 568 (~~566~~ ~~567~~) (~~565~~)	AT 71 69	°F	A64	3-24-75
Minor Dia. 405540±.000010	is .405545 540 (~~537~~) (~~537~~)	AT 71 69	°F	A64	3-24-75
Surface Finish	is Not Specified	AT	°	N/A	—
Roundness Requirements	is Not Specified	AT	°	N/A	—

DCASR 4/4/75

Scratches

ELECTROSTATIC GYROSCOPE

MICRON

FINAL DATA PACKAGE

Control S/N #23

Rotor P/N 12504-302 Rev Orig

					Q.A.	Date
1)	Major Dia. 405570±.000005	is .405571	AT 68 °		ACA	5-8-75
2)	Minor Dia. 405540±.000010	is .405545	AT 68 °		ACA	5-8-75
3)	Surface Finish	is Not Specified	AT °		N/A	
4)	Roundness Requirements	is Not Specified	AT °		N/A	

DCASR C B 0515

(1/30/75)

ELECTROSTATIC GYROSCOPE

MICRON

FINAL DATA PACKAGE

Control S/N N0001

Cavity Assy. Rotor 12700-302 Rev. ________

			Q.A.	Date
)	Spherical cavities to be aligned concentric with in .000050	.000010 At 72.5 °	[signature]	2/3/7
)	Visual of index mark		[signature]	2/3/7
)	16 √ On 0.750 Dim.		[signature]	2/3/7
)	.750 Min. Dia 100% Clean Up		[signature]	2/3/7
)	.005 Clean Up Max		[signature]	2/3/7
)	0.680 $^{+000}_{-.040}$		[signature]	2/3/7
)	Part Identification and tagging		[signature]	2/3/7

DCASR ________________

DATE 2/4/75

rm ESG-M-1 (1/20/75)

ELECTROSTATIC GYROSCOPE

MICRON

FINAL DATA PACKAGE

Control S/N N 0001

	Cavity Rotor Plated 12699-302-1 Rev			Q.A.	DATE
1)	.406250±000010	is .406250	AT 72.5°		2/3/75
2)	Equator Position .000005±000003	is .000004	AT 72.5°		2/3/75
3)	Flatness .000002	is w/in .000002	AT 72.5°		2/3/75
4)	Symmetry $\boxed{A\ B\ .0005}$ 4 Places	is w/in .0005			2/3/75
5)	90°0' ± 0°5' 4 Places				2/3/75
6)	Index Mark 90° ± 10° x .005 to .015				2/3/75
7)	.050 Max Plating				2/3/75
8)	.010 ± .001 Slot				2/4/75
9)	Visual of Plating a) Plate through 4 holes				2/3/75
	b) Continuous Plating Equator Slot spot face and cavity				2/3/75
	c) 4 holes not plated				2/3/75
10)	Roundness 10 µ	is	AT °		

DCASR

DATE 2/4/75

Control S/N N 0001

	Cavity Rotor Plated 12699-302-3 Rev			Q.A.	DATE
1)	.406250 ± 000010	is .406250	AT 72.5°		2/3/75
2)	Equator Position .000005 ± 000003	is .000004	AT 72.5°		2/3/75
3)	Flatness .000002	is w/in .000002	AT 72.5°		2/3/75
4)	Symmetry $\boxed{A\ B\ .0005}$ 4 Places	is w/in .0005			2/3/75
5)	90°0' ± 0 5' 4 places				2/3/75
6)	Index mark 90° ± 10° X.005 to .015				2/3/75
7)	.050 Max Plating				2/3/75
8)	.010 ± .001 Slot				2/3/75
9)	Visual of Plating a) Plate through 4 holes				2/3/75
	b) Continuous Plating Equator Slot spot face and Cavity				2/3/75
	c) 4 Holes not plated				2/3/75
10)	Roundness 10 µ	is	AT °		

DCASR

DATE 2/4/75

ELECTROSTATIC GYROSCOPE

MICRON

FINAL DATA PACKAGE

Control S/N N002

Cavity Assy. Rotor 12700-302 Rev. ________

			Q.A.	Date
Spherical cavities to be aligned concentric with in .000050	W/IN .000010	At 72 °		2/26/75
Visual of index mark				2/26/75
16√ On 0.750 Dim.				2/26/75
.750 Min. Dia 100% Clean Up				2/26/75
.005 Clean Up Max				2/26/75
0.680 $^{+000}_{-.040}$				2/26/75
Part Identification and tagging				2/26/75

DCASR ________

DATE 2-27-75

m ESG-M-1 (1/30/75)

ELECTROSTATIC GYROSCOPE

MICRON

FINAL DATA PACKAGE

Control S/N N0002

Cavity Rotor Plated 12699-302-1 Rev ________

				Q.A.	DATE
1)	.406250±000010	is .406250	AT 71 °		2/27/7
2)	Equator Position .000005±000003	is .000005	AT 71 °		2/27/7
3)	Flatness .000002	is .000002	AT 71 °		2/27/7
4)	Symmetry [A|B|.0005] 4 Places	is w/in .0005			2/27/
5)	90°0' ± 0°5' 4 Places				2/27/7
6)	Index Mark 90° ± 10° x .005 to .015				2/27/7
7)	.050 Max Plating				2/27/7
8)	.010 ± .001 Slot				2/27/7
9)	Visual of Plating a) Plate through 4 holes				2/27/7
	b) Continuous Plating Equator Slot spot face and cavity				2/27/7
	c) 4 holes not plated				2/27/7
10)	Roundness 10 μ	is w/in .000005	AT 71 °		2/27/7

DCASR ________

DATE ________

Control S/N N0002

Cavity Rotor Plated 12699-302-3 Rev ________

				Q.A.	DATE
1)	.406250 ± 000010	is .406250	AT 71 °		2/27/7
2)	Equator Position .000005 ± 000003	is .000005	AT 71 °		2/27/7
3)	Flatness .000002	is .000002	AT 70 °		2/27/7
4)	Symmetry [A|B|.0005] 4 Places	is w/in .0005			2/27/7
5)	90°0' ± 0 5' 4 places				2/27/7
6)	Index mark 90° ± 10° X.005 to .015				2/27/7
7)	.050 Max Plating				2/27/7
8)	.010 ± .001 Slot				2/27/7
9)	Visual of Plating a) Plate through 4 holes				2/27/7
	b) Continuous Plating Equator Slot spot face and Cavity				2/27/7
	c) 4 Holes not plated				2/27/7
10)	Roundness 10 μ	is w/in .000005	AT 71 °		2/27/7

DCASR ________

DATE 2-27-75

Form ESG-M-2 (1/30/75)

ELECTROSTATIC GYROSCOPE

MICRON

FINAL DATA PACKAGE

Control S/N N0003

Cavity Assy. Rotor 12700-302 Rev. ________

				Q.A.	Date
Spherical cavities to be aligned concentric with in .000050	.000010	At	68 °	A64	4-4-75
·isual of index mark				A64	4-4-75
16 ✓ On 0.750 Dim.				A64	4-4-75
750 Min. Dia 100% Clean Up				A54	4-4-75
.005 Clean Up Max				A64	4-4-75
0.680 +000 -.040				A54	4-4-75
Part Identification and tagging					4-4-75

DCASR ________

DATE 4/4/75

ELECTROSTATIC GYROSCOPE

MICRON

FINAL DATA PACKAGE

Control S/N N0003

	Cavity Rotor Plated 12699-302-1 Rev			Q.A.	DATE
1)	.406250±000010	is .406258	AT 68°		4-4-75
2)	Equator Position .000005±000003	is -.000002	AT 68°		4-4-75
3)	Flatness .000002	is .000002	AT 68°		4-4-75
4)	Symmetry [A B .0005] 4 Places	is w/in .0005			4-4-75
5)	90°0' ± 0°5' 4 Places				4-4-75
6)	Index Mark 90° ± 10° x .005 to .015				4-4-75
7)	.050 Max Plating				4-4-75
8)	.010 ± .001 Slot				4-4-75
9)	Visual of Plating a) Plate through 4 holes				4-4-75
	b) Continuous Plating Equator Slot spot face and cavity				4-4-75
	c) 4 holes not plated				4-4-75
10)	Roundness 10 μ	is .000005	AT 68°		

DCASR

DATE 4/4/75

Control S/N N0003

	Cavity Rotor Plated 12699-302-3 Rev			Q.A.	DATE
1)	.406250 ± 000010	is .406258	AT 68°		4-4-75
2)	Equator Position .000005 ± 000003	is -.000002	AT 68°		4-4-75
3)	Flatness .000002	is .000002	AT 68°		4-4-75
4)	Symmetry [A B .0005] 4 Places	is w/in .0005			4-4-75
5)	90°0' ± 0 5' 4 places				4-4-75
6)	Index mark 90° ± 10° X.005 to .015				4-4-75
7)	.050 Max Plating				4-4-75
8)	.010 ± .001 Slot				4-4-75
9)	Visual of Plating a) Plate through 4 holes				4-4-75
	b) Continuous Plating Equator Slot spot face and Cavity				4-4-75
	c) 4 Holes not plated				4-4-75
10)	Roundness 10 μ	is .000006	AT 68°		4-4-75

DCASR

DATE 4/4/75

ELECTROSTATIC GYROSCOPE

MICRON

FINAL DATA PACKAGE

Control S/N N0004

Cavity Assy. Rotor 12700-302 Rev. ________

			Q.A.	Date
Spherical cavities to be aligned concentric with in .000050	.000010	At 68°	A54	4-4-75
Visual of index mark			A54	4-4-75
16✓ On 0.750 Dim.			A54	4-4-75
.750 Min. Dia 100% Clean Up			A54	4-4-75
.005 Clean Up Max			A54	4-4-75
$0.680 \begin{smallmatrix}+000 \\ -.040\end{smallmatrix}$			A54	4-4-75
Part Identification and tagging			A54	4-4-75

DCASR ________

DATE 4/4/75

ESG-M-1 (1/30/75)

ELECTROSTATIC GYROSCOPE

MICRON

FINAL DATA PACKAGE

Control S/N N0004

	Cavity Rotor Plated 12699-302-1 Rev			Q.A.	DATE
1)	.406250±000010	is .406248	AT 68°	A64	4-4-75
2)	Equator Position .000005±000003	is -.000003	AT 68°	A64	4-4-75
3)	Flatness .000002	is .000002	AT 68°	A64	4-4-75
4)	Symmetry $\boxed{A \mid B \mid .0005}$ 4 Places	is W/IN .0005		A64	4-4-75
5)	90°0' ± 0°5' 4 Places			A64	4-4-75
6)	Index Mark 90° ± 10° x .005 to .015			A64	4-4-75
7)	.050 Max Plating			A64	4-4-75
8)	.010 ± .001 Slot			A64	4-4-75
9)	Visual of Plating a) Plate through 4 holes			A64	4-4-75
	b) Continuous Plating Equator Slot spot face and cavity			A64	4-4-75
	c) 4 holes not plated			A64	4-4-75
10)	Roundness 10 µ	is .000005	AT 68°		

DCASR C B CS15

DATE 4/4/75

Control S/N N0004

	Cavity Rotor Plated 12699-302-3 Rev			Q.A.	DATE
1)	.406250 ± 000010	is .406248	AT 68°	A64	4-4-75
2)	Equator Position .000005 ± 000003	is -.000003	AT 68°	A64	4-4-75
3)	Flatness .000002	is .000002	AT 68°	A64	4-4-75
4)	Symmetry $\boxed{A \mid B \mid .0005}$ 4 Places	is W/IN .0005		A64	4-4-75
5)	90°0' ± 0 5' 4 places			A64	4-4-75
6)	Index mark 90° ± 10° X.005 to .015			A64	4-4-75
7)	.050 Max Plating			A64	4-4-75
8)	.010 ± .001 Slot			A64	4-4-75
9)	Visual of Plating a) Plate through 4 holes			A64	4-4-75
	b) Continuous Plating Equator Slot spot face and Cavity			A64	4-4-75
	c) 4 Holes not plated			A64	4-4-75
10)	Roundness 10 µ	is .000006	AT 68°	A64	4-4-75

DCASR C Q CS15

DATE 4/4/75

ELECTROSTATIC GYROSCOPE

MICRON

FINAL DATA PACKAGE

Control S/N N0005

Cavity Assy. Rotor 12700-302 Rev. ______

			Q.A.	Date
Spherical cavities to be aligned concentric with in .000050	.000010	At 68 °	A64	5-9-75
Visual of index mark			A64	5-9-75
16 ✓ On 0.750 Dim.			A64	5-9-75
.750 Min. Dia 100% Clean Up			A64	5-9-75
.005 Clean Up Max			A64	5-9-75
0.680 $^{+000}_{-.040}$			A64	5-9-75
Part Identification and tagging			A64	5-9-75

DCASR ____________

DATE 09 MAY 1975

ELECTROSTATIC GYROSCOPE

MICRON

FINAL DATA PACKAGE

Control S/N N0005

	Cavity Rotor Plated 12699-302-1 Rev			Q.A.	DATE
1)	.406250±000010	is .406245	AT 68°	A64	5-9-75
2)	Equator Position .000005±000003	is .000005	AT 68°	A64	5-9-75
3)	Flatness .000002	is .000002	AT 68°	A64	5-9-75
4)	Symmetry [A|B|.0005] 4 Places	is W/IN .0005		A64	5-9-75
5)	90°0' ± 0°5' 4 Places			A64	5-9-75
6)	Index Mark 90° ± 10° x .005 to .015			A64	5-9-75
7)	.050 Max Plating			A64	5-9-75
8)	.010 ± .001 Slot			A64	5-9-75
9)	Visual of Plating a) Plate through 4 holes			A64	5-9-75
	b) Continuous Plating Equator Slot spot face and cavity			A64	5-9-75
	c) 4 holes not plated			A64	5-9-75
10)	Roundness 10 μ	is .000007	AT 68°	A64	5-9-75

DCASR ______

DATE 09 MAY 1975

Control S/N N0005

	Cavity Rotor Plated 12699-302-3 Rev			Q.A.	DATE
1)	.406250 ± 000010	is .406245	AT 68°	A64	5-9-75
2)	Ecuator Position .000005 ± 000003	is .000003	AT 68°	A64	5-9-75
3)	Flatness .000002	is .000002	AT 68°	A64	5-9-75
4)	Symmetry [A|B|.0005] 4 Places	is W/IN .0005		A64	5-9-75
5)	90°0' ± 0 5' 4 places			A64	5-9-75
6)	Index mark 90° ± 10° X.005 to .015			A64	5-9-75
7)	.050 Max Plating			A64	5-9-75
8)	.010 ± .001 Slot			A64	5-9-75
9)	Visual of Plating a) Plate through 4 holes			A64	5-9-75
	b) Continuous Plating Equator Slot spot face and Cavity			A64	5-9-75
	c) 4 Holes not plated			A64	5-9-75
10)	Roundness 10 μ	is .000007	AT 68°	A64	5-9-75

DCASR ______

DATE 09 MAY 1975

Form EDG-M-2 (1/30/75)

ELECTROSTATIC GYROSCOPE

MICRON

FINAL DATA PACKAGE

Control S/N N0006

Cavity Assy. Rotor 12700-302 Rev. ________

			Q.A.	Date
) Spherical cavities to be aligned concentric with in .000050	.000010	At 68 °	ACA	5-9-75
) Visual of index mark			ACA	5-9-75
16✓ On 0.750 Dim.			ACA	5-9-75
) .750 Min. Dia 100% Clean Up			ACA	5-9-75
) .005 Clean Up Max			ACA	5-9-75
) 0.680 $^{+000}_{-.040}$			ACA	5-9-75
) Part Identification and tagging			ACA	5-9-75

DCASR ________

DATE 09 MAY 1975

orm ESG-M-1 (1/30/75)

ELECTROSTATIC GYROSCOPE

MICRON

FINAL DATA PACKAGE

Control S/N N0006

Cavity Rotor Plated 12699-302-1 Re

			DATE
1)	.406250±000010		5-9-75
2)	Equator Position .000005±000003		5-9-75
3)	Flatness .000002		5-9-75
4)	Symmetry $\boxed{A\,|\,B\,|\,.0005}$ 4 Places		5-9-75
5)	90°0' ± 0°5' 4 Places		5-9-75
6)	Index Mark 90° ± 10° x .005 to .015		5-9-75
7)	.050 Max Plating		5-9-75
8)	.010 ± .001 Slot		5-9-75
9)	Visual of Plating a) Plate through 4 holes		5-9-75
	b) Continuous Plating Equator Slot spot face and cavity		5-9-75
	c) 4 holes not plated		5-9-75
10)	Roundness 10 µ is .000005 AT 68 °		5-9-75

DCASR ______

DATE ______

Control S/N N0006

Cavity Rotor Plated 12699-302-3 Rev ______

				Q.A.	DATE
1)	.406250 ± 000010	is .406243	AT 68 °		5-9-75
2)	Equator Position .000005 ± 000003	is .000004	AT 68 °		5-9-75
3)	Flatness .000002	is .000002	AT 68 °		5-9-75
4)	Symmetry $\boxed{A\,|\,B\,|\,.0005}$ 4 Places	is W/IN .0005			5-9-75
5)	90°0' ± 0 5' 4 places				5-9-75
6)	Index mark 90° ± 10° X.005 to .015				5-9-75
7)	.050 Max Plating				5-9-75
8)	.010 ± .001 Slot				5-9-75
9)	Visual of Plating a) Plate through 4 holes				5-9-75
	b) Continuous Plating Equator Slot spot face and Cavity				5-9-75
	c) 4 Holes not plated				5-9-75
10)	Roundness 10 µ	is 000005	AT 68 °		5-9-75

DCASR ______

DATE 09 MAY 1975

ELECTROSTATIC GYROSCOPE

MICRON

FINAL DATA PACKAGE

Control S/N NA0007
(NA 1 & NA 9)

Cavity Assy. Rotor 12700-302 Rev. 1

				Q.A.	Date
Spherical cavities to be aligned concentric with in .000050	w/in .000010	At	68°		1-2-76
Visual of index mark					1-2-76
16 ✓ On 0.750 Dim.					1-2-76
.750 Min. Dia 100% Clean Up					1-2-76
.005 Clean Up Max					1-2-76
0.680 $^{+000}_{-.040}$					1-2-76
Part Identification and tagging					1-2-76

DCASR

DATE 1-2-76

n ESG-M-1 (1/30/75)

ELECTROSTATIC GYROSCOPE

MICRON

FINAL DATA PACKAGE

NA 0007

Control S/N NA-1

Cavity Rotor Plated 12699-302-1 Rev 2 (3-28-75)

				Q.A.	DATE
1)	.406250±000010	is .406254	AT 68°		1-2-76
2)	Equator Position .000005±000003	is .000006	AT 68°		1-2-76
3)	Flatness .000010 convex	is w/in 10μ" convex	AT 68°		1-2-76
4)	Symmetry $\boxed{A \mid E \mid .0005}$ 4 Places	is w/in .0005			1-2-76
5)	90°0' ± 0°5' 4 Places				1-2-76
6)	Index Mark 90° ± 10° x .005 to .015				1-2-76
7)	.050 Max Plating				1-2-76
8)	.005 ±.001				1-2-76
9)	Visual of Plating a) Plate through 4 holes				1-2-76
	b) Continuous Plating Equator Slot spot face and cavity				1-2-76
	c) 4 holes not plated				1-2-76
10)	Roundness 10 μ	is N/A	AT °		1-2-76

DCASR ______

DATE 1-2-76

Control S/N NA-9

Cavity Rotor Plated 12699-302-3 Rev 2 (3-28-75)

				Q.A.	DATE
1)	.406250 ± 000010	is .406254	AT 68°		1-2-76
2)	Equator Position .000005 ± 000003	is .000006	AT 68°		1-2-76
3)	Flatness .000010 convex	is w/in 10μ" convex	AT 68°		1-2-76
4)	Symmetry $\boxed{A \mid B \mid .0005}$ 4 Places	is w/in .0005			1-2-76
5)	90°0' ± 0 5' 4 places				1-2-76
6)	Index mark 90° ± 10° X.005 to .015				1-2-76
7)	.050 Max Plating				1-2-76
8)	.005 ±.001				1-2-76
9)	Visual of Plating a) Plate through 4 holes				1-2-76
	b) Continuous Plating Equator Slot spot face and Cavity				1-2-76
	c) 4 Holes not plated				1-2-76
10)	Roundness 10 μ	is N/A	AT °		1-2-76

DCASR ______

DATE 1-2-76

ELECTROSTATIC GYROSCOPE

MICRON

FINAL DATA PACKAGE

Control S/N NA0008
(NA4 & NA12)

Cavity Assy. Rotor 12700-302 Rev. /

				Q.A.	Date
1)	Spherical cavities to be aligned concentric with in .000050	w/in .000010	At 68 °		1-2-76
2)	Visual of index mark				1-2-76
3)	16✓ On 0.750 Dim.				1-2-76
4)	.750 Min. Dia 100% Clean Up				1-2-76
5)	.005 Clean Up Max				1-2-76
6)	$0.680 \begin{smallmatrix}+000 \\ -.040\end{smallmatrix}$				1-2-76
7)	Part Identification and tagging				1-2-76

DCASR

DATE 1-2-76

orm ESG-M-1 (1/30/75)

ELECTROSTATIC GYROSCOPE

MICRON

FINAL DATA PACKAGE

NA 0008
Control S/N NA-4

	Cavity Rotor Plated 12699-302-1 Rev 2 (3-28-75)		Q.A.	DATE
1)	.406250±000010	is .406246 AT 68°		1-2-76
2)	Equator Position .000005±000003	is .000006 AT 68°		1-2-76
3)	Flatness .000010 CONVEX	is w/in 10μ" CONVEX AT 68°		1-2-76
4)	Symmetry $\boxed{A \mid B \mid .0005}$ 4 Places	is w/in .0005		1-2-76
5)	90°0' ± 0°5' 4 Places			1-2-76
6)	Index Mark 90° ± 10° x .005 to .015			1-2-76
7)	.050 Max Plating			1-2-76
8)	.005 ± .001			1-2-76
9)	Visual of Plating a) Plate through 4 holes			1-2-76
	b) Continuous Plating Equator Slot spot face and cavity			1-2-76
	c) 4 holes not plated			1-2-76
10)	Roundness 10 μ	is N/A AT °		1-2-76

DCASR ____________

DATE 1-2-76

NA 0008
Control S/N NA-12

	Cavity Rotor Plated 12699-302-3 Rev 2 (3-28-75)		Q.A.	DATE
1)	.406250 ± 000010	is .406246 AT 68°		1-2-76
2)	Equator Position .000005 ± 000003	is .000005 AT 68°		1-2-76
3)	Flatness .000010 CONVEX	is w/in 10μ" CONVEX AT 68°		1-2-76
4)	Symmetry $\boxed{A \mid B \mid .0005}$ 4 Places	is w/in .0005		1-2-76
5)	90°0' ± 0 5' 4 places			1-2-76
6)	Index mark 90° ± 10° X.005 to .015			1-2-76
7)	.050 Max Plating			1-2-76
8)	.005 ± .001			1-2-76
9)	Visual of Plating a) Plate through 4 holes			1-2-76
	b) Continuous Plating Equator Slot spot face and Cavity			1-2-76
	c) 4 Holes not plated			1-2-76
10)	Roundness 10 μ	is N/A AT °		1-2-76

DCASR ____________

DATE 1-2-76

Form ESG-M-2 (1/30/75)

ELECTROSTATIC GYROSCOPE

MICRON

FINAL DATA PACKAGE

Control S/N NA0009 (NA2 & NA10)

Cavity Assy. Rotor 12700-302 Rev. 1 (3-28-75)

			Q.A.	Date
1)	Spherical cavities to be aligned concentric with in .000050	w/in 000010 At 68 °	A64	2/11/76
2)	Visual of index mark		A64	2/11/76
3)	16✓ On 0.750 Dim.		A64	2/11/76
4)	.750 Min. Dia 100% Clean Up		A64	2/11/76
5)	.005 Clean Up Max		A64	2/11/76
6)	0.680 $^{+000}_{-.040}$		A64	2/11/76
7)	Part Identification and tagging		A64	2/11/76
8)	1000 megohms min. test		A64	2/11/76

C 0512 B

DCASR ______

DATE 2/11/76

Form ESG-M-1 (1/30/75)

ELECTROSTATIC GYROSCOPE

MICRON

FINAL DATA PACKAGE

NA 0009
Control S/N NA 2

Cavity Rotor Plated 12699-302-1 Rev 2 (3-28-75)

				Q.A.	DATE
1)	.406250±000010	is .406258	AT 68°	A64	2/11/76
2)	Equator Position .000005±000003	is .000005	AT 68°	A64	2/11/76
3)	Flatness .000010	is w/in 10μ convex	AT 68°	A64	2/11/76
4)	Symmetry |A|B|.0005| 4 Places	is w/in .0005		A64	2/11/76
5)	90°0' ± 0°5' 4 Places			A64	2/11/76
6)	Index Mark 90° ± 10° x .005 to .015			A64	2/11/76
7)	.050 Max Plating			A64	2/11/76
8)	.005 ± .001 Slot			A64	2/11/76
9)	Visual of Plating a) Plate through 4 holes			A64	2/11/76
	b) Continuous Plating Equator Slot spot face and cavity			A64	2/11/76
	c) 4 holes not plated			A64	2/11/76
10)	Roundness 10 μ	is N/A	AT °		

DCASR ______

DATE ______

NA 0009
Control S/N NA 10

Cavity Rotor Plated 12699-302-3 Rev 2 (3-28-75)

				Q.A.	DATE
1)	.406250 ± 000010	is .406258	AT 68°	A64	2/11/76
2)	Equator Position .000005 ± 000003	is .000005	AT 68°	A64	2/11/76
3)	Flatness .000010	is w/in 10μ convex	AT 68°	A64	2/11/76
4)	Symmetry |A|B|.0005| 4 Places	is w/in .0005		A64	2/11/76
5)	90°0' ± 0 5' 4 places			A64	2/11/76
6)	Index mark 90° ± 10° X.005 to .015			A64	2/11/76
7)	.050 Max Plating			A64	2/11/76
8)	.005 ± .001 Slot			A64	2/11/76
9)	Visual of Plating a) Plate through 4 holes			A64	2/11/76
	b) Continuous Plating Equator Slot spot face and Cavity			A64	2/11/76
	c) 4 Holes not plated			A64	2/11/76
10)	Roundness 10 μ	is N/A	AT		

0512

DCASR ______

DATE 2/11/76

Form ESG-M-2 (1/30/75)

ELECTROSTATIC GYROSCOPE

MICRON

FINAL DATA PACKAGE

Control S/N NA0010 (NA3 & NA11)

Cavity Assy. Rotor 12700-302 Rev. 1 (3-28-75)

				Q.A.	Date
1)	Spherical cavities to be aligned concentric with in .000050	W/IN 000010	At 68 °	A64	2/11/76
2)	Visual of index mark			A64	2/11/76
3)	16 ✓ On 0.750 Dim.			A64	2/11/76
4)	.750 Min. Dia 100% Clean Up			A64	2/11/76
5)	.005 Clean Up Max			A64	2/11/76
6)	0.680 $^{+000}_{-.040}$			A64	2/11/76
7)	Part Identification and taggi			A64	2/11/76
8)	1000 megohms min. test			A64	2/11/76

C B 0812

DCASR

DATE 2/11/76

Form ESG-M-1 (1/30/75)

ELECTROSTATIC GYROSCOPE

MICRON

FINAL DATA PACKAGE

NA 0010

Control S/N NA 3

Cavity Rotor Plated 12699-302-1 Rev 2 (3-28-75)

			Q.A.	DATE
1)	.406250±000010	is .406251 AT 68°	A64	2/11/76
2)	Equator Position .000005±000003	is .000004 AT 68°	A64	2/11/76
3)	Flatness .000010	is W/IN 10µ" CONVEX AT 68°	A64	2/11/76
4)	Symmetry |A|B|.0005| 4 Places	is W/IN .0005	A64	2/11/76
5)	90°0' ± 0°5' 4 Places		A64	2/11/76
6)	Index Mark 90° ± 10° x .005 to .015		A64	2/11/76
7)	.050 Max Plating		A64	2/11/76
8)	.005 ± .001 Slot		A64	2/11/76
9)	Visual of Plating a) Plate through 4 holes		A64	2/11/76
	b) Continuous Plating Equator Slot spot face and cavity		A64	2/11/76
	c) 4 holes not plated		A64	2/11/76
10)	Roundness 10 µ	is N/A AT °		

DCASR __________

DATE __________

NA 0010

Control S/N NA 11

Cavity Rotor Plated 12699-302-3 Rev 2 (3-28-75)

			Q.A.	DATE
1)	.406250 ± 000010	is .406250 AT 68°	A64	2/11/76
2)	Equator Position .000005 ± 000003	is .000004 AT °	A64	2/11/76
3)	Flatness .000010	is W/IN 10µ" CONVEX AT °	A64	2/11/76
4)	Symmetry |A|B|.0005| 4 Places	is W/IN. .0005	A64	2/11/76
5)	90°0' ± 0 5' 4 places		A64	2/11/76
6)	Index mark 90° ± 10° X.005 to .015		A64	2/11/76
7)	.050 Max Plating		A64	2/11/76
8)	.005 ± .001 Slot		A64	2/11/76
9)	Visual of Plating a) Plate through 4 holes		A64	2/11/76
	b) Continuous Plating Equator Slot spot face and Cavity		A64	2/11/76
	c) 4 Holes not plated		A64	2/11/76
10)	Roundness 10 µ	is N/A AT °		

C S 0512

DCASR __________

DATE 2/11/76

Form ESG-M-2 (1/30/75)

STATE OF CALIFORNIA MEASUREMENT SYSTEM

Autonetics Division
Rockwell International

METROLOGY LABORATORY DATA REPORT

ITEM Nortronics Cavities & Rotors NUMBER Noted

SUBMITTED BY H. Bump DEPT 244

TEMP. @ 68°F

CHARACTERISTIC	TOLERANCE	MEASUREMENT
Spherical Diameter		
NA0001 Cavity 12699-302-1	.406250 ± .000010 in.	.406259 in.
NA0001 Cavity 12699-302-3	.406250 ± .000010 in.	.406259 in.
Cavity N-1	.406250 ± .000010 in.	.406272 in.
Rotor #7	.405650 ± .000010 in.	.405648 in.
Rotor #2	Not Specified	.405572 in.
7-16		.405572 + .405522
Equator Location		
Cavity 12699-302-1	-.000005 ± .000003 in.	+.000006 in.
Cavity 12699-302-3	-.000005 ± .000003 in.	+.000006 in.
Cavity N-1	-.000005 ± .000003 in.	.000000 in.
Sphericity		
Cavity 12699-302-1	.000003 in. TIR	.000005 in. TIR
Cavity 12699-302-3	.000003 in. "	.000003 in. "
Cavity N-1	.000003 in. "	.000002 in. "
Rotor #2	.000005 in. "	.000002 in. TIR Max
Rotor #7	.000005 in. "	.000003 in. TIR Max

COMMENTS:

Sphericity meets requirements of .000010 inch allowable Bell mouth.

JOB NUMBER: ________

DATE: 2-26-75

PAGE 1 OF 2

PREPARED BY G. Kuhn

VERIFIED BY K. Lund K. Lund

850-A-3 REV 2/73

STATE OF CALIFORNIA MEASUREMENT SYSTEM

Autonetics Division
Rockwell International

METROLOGY LABORATORY DATA REPORT

ITEM ____________ NUMBER ____________

SUBMITTED BY ____________ DEPT ____________

CHARACTERISTIC	TOLERANCE	MEASUREMENT
Flatness		
S/N A0001 { Cavity 12699-302-1	.000010 in.	.000003 in.
S/N A0001 { Cavity 12699-302-3	"	.000002 in.
N-1 Cavity	"	.000002 in.
Roundness	Not specified	
Z-16 Rotor		
Over wires		.000012 in.
90^{o} to wires		.000006 in.

COMMENTS:

JOB NUMBER: ____________

DATE: ____________ PREPARED BY ____________

PAGE 2 OF 2 VERIFIED BY ____________

850-A-3 REV 2/73

STATE OF CALIFORNIA MEASUREMENT SYSTEM

Autonetics Division
Rockwell International

METROLOGY LABORATORY DATA REPORT

ITEM Nortronics Cavities & Rotor NUMBER Noted
SUBMITTED BY H. Bump DEPT 244

CHARACTERISTIC	TOLERANCE	MEASUREMENT
Spherical Diameter		
Cavity N0002-1	.406250 ± .000010 in.	.406255 in.
Cavity N0002-3	.406250 ± .000010 in.	.406260 in.
Rotor Z18	Not Specified	
Maximum		.405565 in.
Minimum		.405549 in.
Equator Location		
Cavity N0002-1	-.000005 ± .000003 in.	+.000002 in.
Cavity N0002-3	-.000005 ± .000003 in.	-.000004 in.
Sphericity		
Cavity N0002-1	.000003 in.	.000003 in.
Cavity N0002-3	.000003 in.	.000005 in.
Flatness		
Cavity N0002-1	0.000010 in.	.000005 in.
Cavity N0002-3	0.000010 in.	.000003 in.

COMMENTS:

*Cavity set (N0002-1 and N0002-2) was found to have nickel plate on the back side of the cavity halves. The nickel plating extends thru the cavity holes and would cause electrode short circuit to ground.

H. L. Bump
3/20/75

JOB NUMBER: ________

DATE: 03-18-75

PAGE 1 OF 2

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*Same observation made on first cavity set N0001.

850-A-1 REV 2/73

STATE OF CALIFORNIA MEASUREMENT SYSTEM

Autonetics Division
Rockwell International

METROLOGY LABORATORY DATA REPORT

ITEM Nortronics Cavities & Rotor NUMBER Noted

SUBMITTED BY H. Bump DEPT 244

CHARACTERISTIC	TOLERANCE	MEASUREMENT
Roundness		
Rotor Z-18		
Over wires		
Position 1		.000019 in.
Position 2		.000014 in.
90° to wir		.000002 in.

COMMENTS:

JOB NUMBER: ________

DATE: 03-18-75

PAGE 2 OF 2

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STATE OF CALIFORNIA MEASUREMENT SYSTEM

Autonetics Division
Rockwell International

METROLOGY LABORATORY DATA REPORT

ITEM Northrup ESG Rotor NUMBER Z-16
SUBMITTED BY H. Bunt DEPT 244

CHARACTERISTIC	TOLERANCE	MEASUREMENT
Spherical Diameter	Not Specified	
Maximum		.405542
Minimum		.405522

COMMENTS:

JOB NUMBER:
DATE: 03-25-75
PAGE 1 OF 1

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STATE O, CALIFORNIA MEASUREMENT _YSTEM

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METROLOGY LABORATORY DATA REPORT

ITEM Northrup Cavities and Rotors NUMBER Noted

SUBMITTED BY H. Bump DEPT 244

CHARACTERISTIC	TOLERANCE	MEASUREMENT
Spherical Diameter		
Cavity N005-1	.406250 ± .000010 in.	.406246 in.
Cavity N005-3	.406250 ± .000010 in.	.406246 in.
Cavity N006-1	.406250 ± .000010 in.	.406247 in.
Cavity N006-3	.406250 ± .000010 in.	.406246 in.
Master #7	Not Specified	.406265 in.
BeO Master	Not Specified	.406258 in.
Rotor Z23	Not Specified	
Maximum		.405563 in.
Minimum		.405532 in.
Rotor Z13		
Maximum		.405560 in.
Minimum		.405532 in.
Equator Location		
Cavity N005-1	-.000005 ± .000003 in.	-.000004 in.
Cavity N005-3	-.000005 ± .000003 in.	-.000001 in.
Cavity N006-1	-.000005 ± .000003 in.	-.000001 in.

COMMENTS: All measurements corrected to 68°F.

JOB NUMBER: ________

DATE: 5-15-75

PAGE 1 OF 3

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METROLOGY LABORATORY DATA REPORT

ITEM Northrup Cavities and Rotors NUMBER Noted

SUBMITTED BY H. Bump DEPT 244

CHARACTERISTIC	TOLERANCE	MEASUREMENT
Equator Location		
Cavity N006-3	-.000005 ± .000003 in.	-.000002 in.
Master #7	-.000005 ± .000003 in.	+.000007 in.
BeO Master	-.000005 ± .000003 in.	-.000007 in.
Sphericity		
Cavity N005-1	.000003 in.	.000003 in.
Cavity N005-3	.000003 in.	.000002 in.
Cavity N006-1	.000003 in.	.000002 in.
Cavity N006-3	.000003 in.	.000002 in.
Roundness	Not Specified	
Rotor Z-23		
Over Wires		
Position 1		.000014 in.
Position 2		.000014 in.
90° to Wires		.000002 in.

COMMENTS:

JOB NUMBER:

DATE: 5-15-75

PAGE 2 OF 3

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STATE OF CALIFORNIA MEASUREMENT SYSTEM

Autonetics Division
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METROLOGY LABORATORY DATA REPORT

ITEM Northrup Cavities and Rotors NUMBER Noted

SUBMITTED BY H. Bump DEPT 244

CHARACTERISTIC	TOLERANCE	MEASUREMENT
Roundness	Not Specified	
Rotor Z-13		
Over Wires		
Position 1		.000015 in.
Position 2		.000015 in.
90° to Wires		.000003 in.

COMMENTS:

JOB NUMBER: ________

DATE: 5-15-75

PAGE 3 OF 3

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STATE OF CALIFORNIA MEASUREMENT SYSTEM

Autonetics Division
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METROLOGY LABORATORY DATA REPORT

ITEM NORTHRUP CAVITIES & ROTORS NUMBER NOTED

SUBMITTED BY H. BUMP DEPT 244

CHARACTERISTIC	TOLERANCE	MEASUREMENT
Spherical Diameter	.406250 ±.000010 in.	
N003-1		.406264 in.
N003-3		.406264 in.
N004-1		.406250 in.
N004-3		.406252 in.
Equator Location	-.000005 ±.000003 in.	
N003-1		-.000004 in.
N003-3		-.000001 in.
N004-1		-.000003 in.
N004-3		-.000003 in.
Sphericity	.000003 in.	
N003-1		.000002 in.
N003-3		.000002 in.
N004-1		.000002 in.
N004-3		.000002 in.

COMMENTS: Revised 05-20-75 to include spherical diameter of Rotors Z-20, Z-21 and Z-22. All measurements corrected to 68°F.

DATE: 05-20-75

PAGE 1 OF 3

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850-A-3 REV 2/73

STATE OF CALIFORNIA MEASUREMENT SYSTEM

Autonetics Division
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METROLOGY LABORATORY DATA REPORT

ITEM ____________ NUMBER ____________

SUBMITTED BY ____________ DEPT ____________

CHARACTERISTIC	TOLERANCE	MEASUREMENT
Roundness	Not specified	
Rotor Z-20		
Over wires		
Position 1		.000017 in.
Position 2		.000015 in.
90^{o} to wires		.000002 in.
Rotor Z-21		
Over wires		
Position 1		.000013 in.
Position 2		.000013 in.
90^{o} to wires		.000003 in.
Rotor Z-22		
Over wires		
Position 1		.000015 in.
Position 2		.000014 in.
90^{o} to wires		.000001 in.

COMMENTS:

JOB NUMBER: ________

DATE: 5-20-75 PREPARED BY ____________

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Autonetics Division
Rockwell International

METROLOGY LABORATORY DATA REPORT

ITEM ______ NUMBER ______

SUBMITTED BY ______ DEPT ______

CHARACTERISTIC	TOLERANCE	MEASUREMENT
SPHERICAL DIAMETER	Not specified	
Rotor Z-20		
Minimum		.405535 in.
Maximum		.405560 in.
Rotor Z-21		
Minimum		.405540 in.
Maximum		.405565 in.
Rotor Z-22		
Minimum		.405540 in.
Maximum		.405565

COMMENTS:

JOB NUMBER: ______

DATE: 05-20-75 PREPARED BY ______

PAGE 3 OF 7 VERIFIED BY ______

860-A-7101 V 2/73

STATE OF CALIFORNIA MEASUREMENT SYSTEM

Autonetics Division
Rockwell International

METROLOGY LABORATORY DATA REPORT

ITEM Northrup ESG Cavities NUMBER Noted

SUBMITTED BY H. Bump DEPT 244

CHARACTERISTIC	TOLERANCE	MEASUREMENT
SPHERICAL DIAMETER	Not Specified	
B-1		.406245 in
B-2		.406268 in
#7		.406266 in
EQUATOR LOCATION	Not Specified	
B-1		+.000005 in
B-2		-.000002 in
#7		+.000011 in
SPHERICITY	Not Specified	
B-1		.000002 in TIR
B-2		.000003 in TIR
#7		.000004 in TIR

COMMENTS: Cavity thermal coefficients of expansion:

Be0 1.5 μ in/.40625 in/°F

Stainless Stell 2.5 μ in/.40625 in/°F

Meehanite 2.7 μ in/.40625 in/°F

JOB NUMBER: ________

DATE: September 12, 1975

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850-A-3 REV 2/73

STATE OF CALIFORNIA MEASUREMENT SYSTEM

Autonetics Division
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METROLOGY LABORATORY DATA REPORT

ITEM Northrup ESG Parts NUMBER Noted
SUBMITTED BY H. Bump DEPT 244

	CHARACTERISTIC	TOLERANCE	MEASUREMENT
Cavity	Spherical Diameter		
	NA1		.406251 inch
	NA9		.406252
	NA4		.406246
	NA12		.406245
	B-1		.406243
	N-7		.406260
Cavity	Equator Location	Not Specified	
	NA1		-.000008 inch
	NA9		-.000006
	NA4		-.000005
	NA12		-.000004
	B-1		+.000006
	N-7		+.000014

COMMENTS: All measurements corrected to 68°F

Coefficients of Expansion used:
BeO = 2.8 μin/in/$^{\circ}$F
Stainless Steel = 5.6 μin/in/$^{\circ}$F

JOB NUMBER: ______
DATE: January 12, 1976 PREPARED BY K. J. Lund
PAGE 1 OF 3 VERIFIED BY K. J. Lund

STATE OF CALIFORNIA MEASUREMENT SYSTEM

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METROLOGY LABORATORY DATA REPORT

ITEM Northrup ESG Parts NUMBER ____

SUBMITTED BY ____ DEPT ____

	CHARACTERISTIC	TOLERANCE	MEASUREMENT
Cavity	Sphericity	Not Specified	
	NA1		.000002 inch
	NA9		.000002
	NA4		.000003
	NA12		.000003
	B-1		.000003
	N-7		.000005
C[illegible]y	Bellmouth	Not Specified	
	NA1		.000010 inch
	NA9		.000007
	NA4		.000010
	NA12		.000013
	B-1		.000007
	N-7		.000005

COMMENTS:

JOB NUMBER: ____

DATE: ____

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STATE OF CALIFORNIA MEASUREMENT SYSTEM

Autonetics Division
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METROLOGY LABORATORY DATA REPORT

ITEM Northrup ESG Parts NUMBER ______
SUBMITTED BY ______ DEPT ______

CHARACTERISTIC	TOLERANCE	MEASUREMENT
Rotor Spherical Diameter (1)	Not Specified	
NA11		.405552 inch
NA16		.405552 inch
Rotor Sphericity	Not Specified	
NA11		
Position 1		
Position 2		.000014 inch
Position 3		.000014
90° to Wires		.000013
NA16		.000001
Position 1		.000014
Position 2		.000014
Position 3		.000014
90° to Wires		.000001

COMMENTS: (1) Average Diameter of Major and Minor Axes

JOB NUMBER: ______
DATE: ______
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STATE OF CALIFORNIA MEASUREMENT SYSTEM

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METROLOGY LABORATORY DATA REPORT

ITEM Northrup ESG Parts NUMBER Noted

SUBMITTED BY H. Bump DEPT 244

CHARACTERISTIC	TOLERANCE	MEASUREMENT
CAVITY SPHERICAL DIAMETER	Not Specified	
NA #10		.406252 inch
NA #2		.406256 inch
NA #11		.406248 inch
NA #3		.406249 inch
CAVITY EQUATOR LOCATION	Not Specified	
NA#10		.000000 inch
NA #2		-.000004 inch
NA #11		-.000007 inch
NA #3		-.000003 inch
CAVITY SPHERICITY	Not Specified	
NA #10		.000002 inch TIR
NA #2		.000003 inch TIR
NA #11		.000004 inch TIR
NA #3		.000003 inch TIR

COMMENTS:

Recd SSD 17 May 76

JOB NUMBER: ______

DATE: 3-22-76

PAGE 1 OF 15

PREPARED BY C. Kuhn

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METROLOGY LABORATORY DATA REPORT

ITEM Northrup ESG Parts NUMBER

SUBMITTED BY DEPT

CHARACTERISTIC	TOLERANCE	MEASUREMENT
CAVITY BELLMOUTH	Not Specified	
NA #10		.000005 inch
NA#2		.000007 inch
NA #11		.000008 inch
NA #3		.000007 inch
ROTOR SPHERICAL DIAMETER(1)	Not Specified	
NA-14		.405552 inch
NA-22		.405559 inch
ROTOR SPHERICITY	Not Specified	
NA-14		
Position #1		.000015 inch TIR
Position #2		.000015 inch TIR
Position #3		.000015 inch TIR
90° to wires		.000001 inch TIR

COMMENTS: (1)Average Diameter of Major and Minor Axes

JOB NUMBER:

DATE: 03-22-76

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850-A-3 REV 2/73

STATE OF CALIFORNIA MEASUREMENT SYSTEM

Autonetics Division
Rockwell International

METROLOGY LABORATORY DATA REPORT

ITEM Northrup ESG Parts NUMBER ____________
SUBMITTED BY ____________ DEPT ____________

CHARACTERISTIC	TOLERANCE	MEASUREMENT
ROTOR SPHERICITY	Not Specified	
NA-22		
Position #1		.000014 inch TIR
Position #2		.000012 inch TIR
Position #3		.000013 inch TIR
90° to wires		.000002 inch TIR

COMMENTS:

JOB NUMBER: ________
DATE: 03-22-76
PAGE 3 OF 15

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VERIFIED BY [signature]

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5-7